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VOL. XXXVIII. — No. 2. FEBRUARY 1961.

Monthly Bulletin of the International Railway Congress Association

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Bulletin of the International Railway Congress Association

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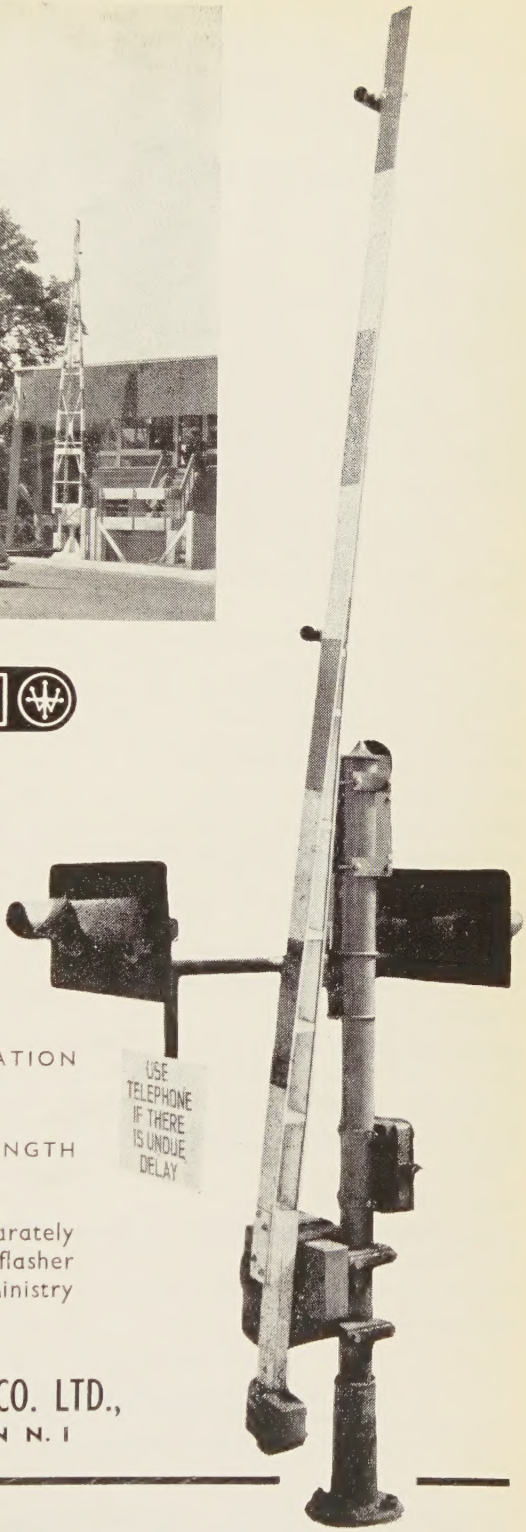

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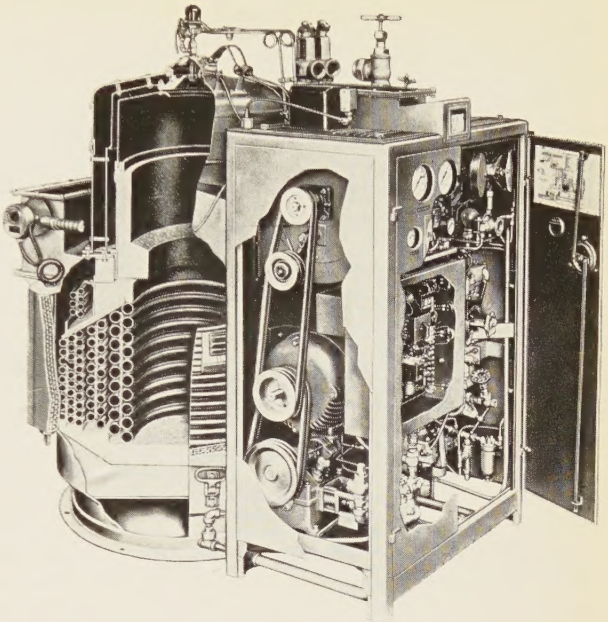

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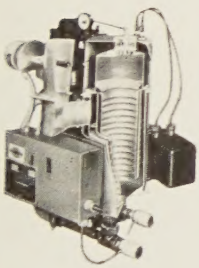

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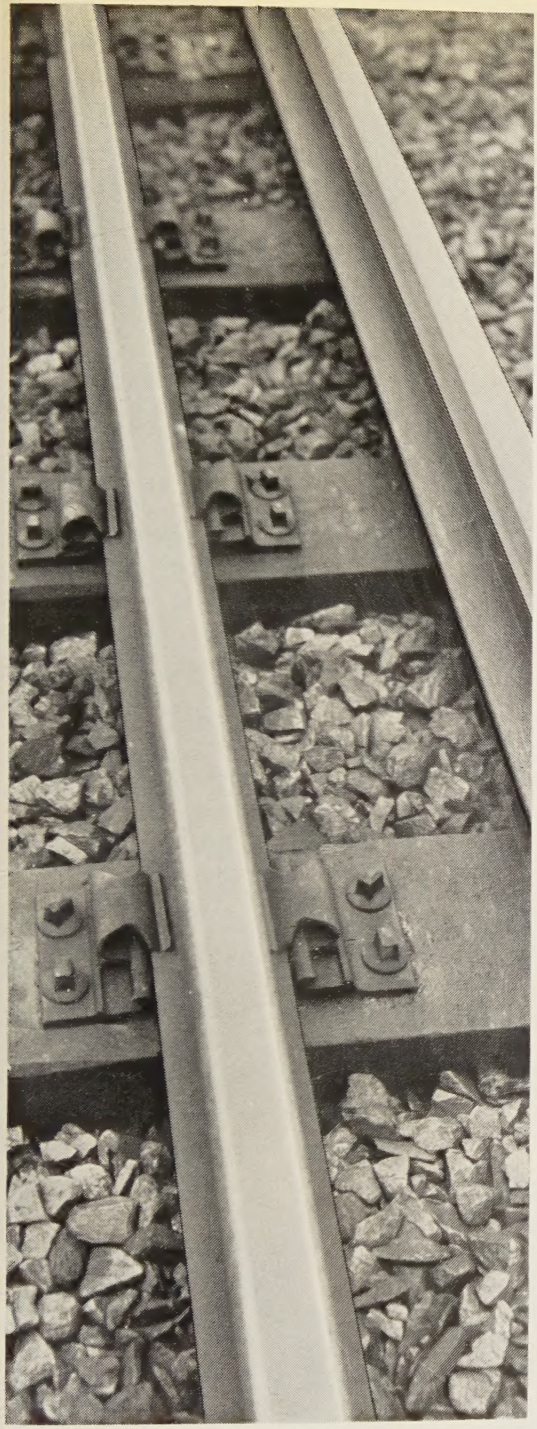

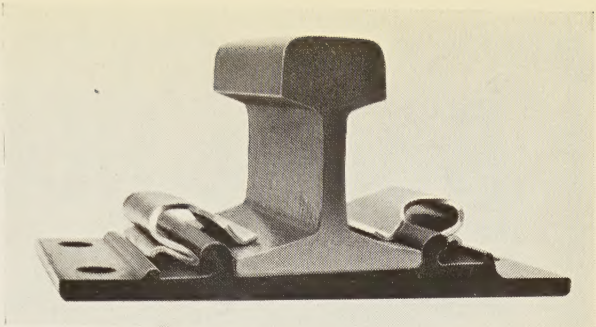

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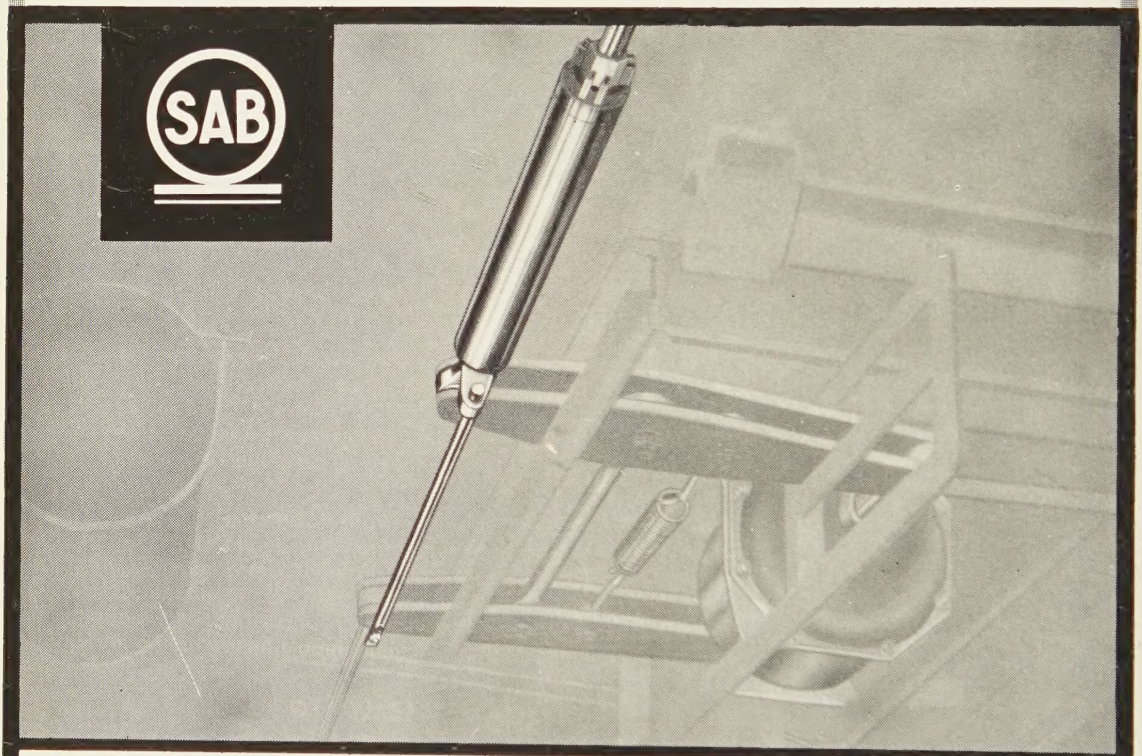

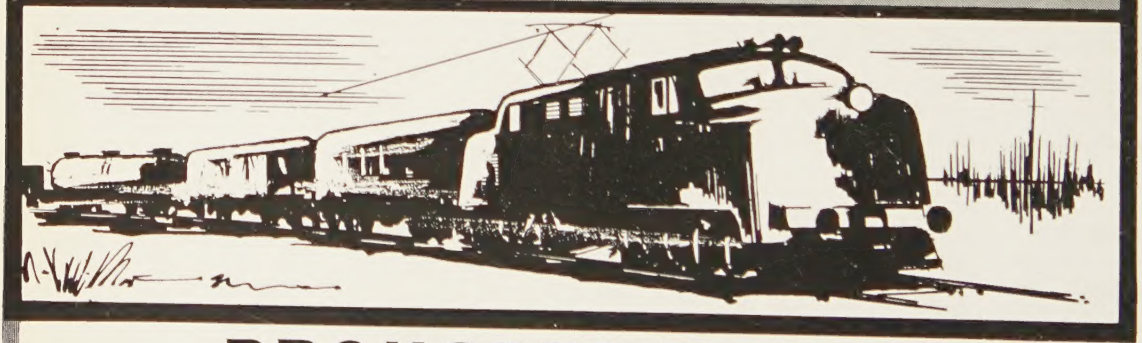

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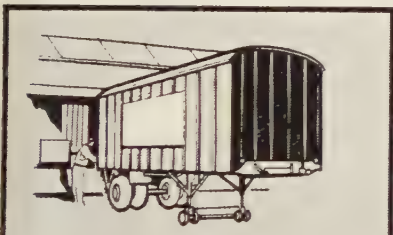

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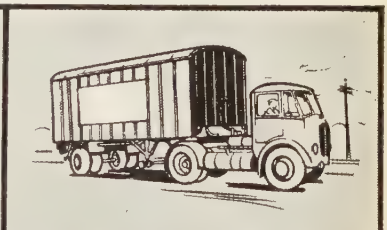

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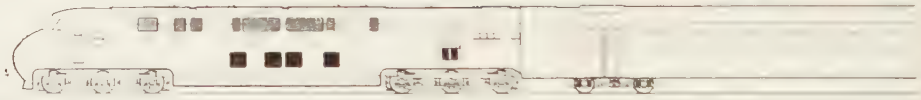

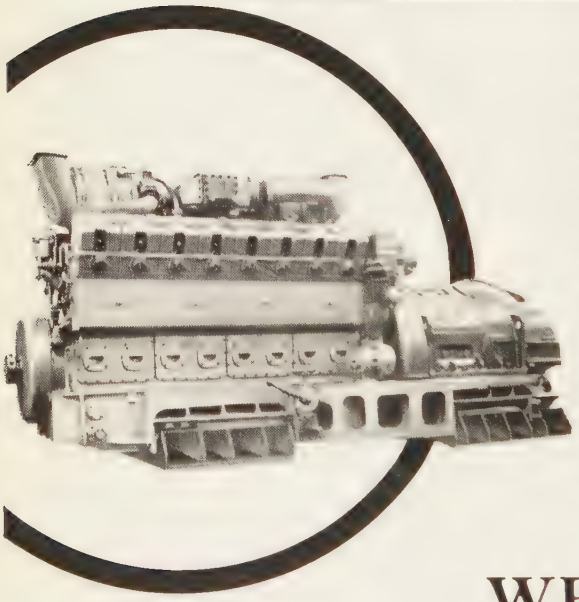

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Price of this single copy : 80 Belgian Francs (not including postage).

Yearly subscription for 1961 { Belgium . . . . . 700 Belgian Francs
Universal Postal Union . . . 800 Belgian Francs

Subscriptions and orders for single copies to be addressed to the General Secretary, International Railway Congress Association, 19, rue du Beau-Site, Brussels (Belgium).

Advertisements : All communications should be addressed to the Association, 19, rue du Beau-Site, Brussels (Telephone No. 47.53.35).

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Vol. XXXVIII. — No. 2. February 1961.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
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(ENGLISH EDITION)

[656 .223 .2]

The circulation of empty wagons in railway networks,

by Professor Dr. W. Wyrzykowski.

The purpose of the present study is to establish a method which will enable the circulation of empty wagons in railway networks to be ascertained, analysed and appraised, and to be organized in a rational manner.

It is well known that empty wagons may be encountered in a railway region during greatly different phases of operation. In this respect, one might adopt the following classification :

1. Empty wagons carrying out a given trip (measurable in axle kilometres) from the unloading yard to the loading yard, both situated in the same region, or a trip from the unloading yard (situated in the region surveyed) to the wagon re-forwarding and reception yard (inter-regional wagon exchange yard; border station), or finally a trip from the re-forwarding and reception yard to a loading yard situated in the region surveyed; all these trips form part of the local outgoing and incoming traffic; they are comprised in the wagon turn-round serving the railway region concerned, and cover the wagon loading and unloading requirements in the region itself. (*)

2. Empty wagons carrying out a given trip (measurable in axle kilometres) between inter-regional wagon exchange yards of the region concerned; these trips represent transit traffic in respect of the region surveyed, and have nothing to do with the wagon turn-round within that region.

3. Empty wagons stabled at the loading or unloading yards; this stabling time is taken to include the period from the arrival of the empty wagon at the loading yard to the moment at which the loading operation begins, or the period from the moment at which the unloading operation is completed to the departure of the empty wagon from the unloading yard, or finally the period from the completion of the unloading operation to the beginning of the subsequent loading operation in the same

(*) W. Wyrzykowski, « A Method to calculate the circulation and round-trip times of wagons in railway regions », *Bulletin of the International Railway Congress Association*, November, 1959.

yard. This latter case may be termed a « double loading operation ».

4. Empty wagons stabled at junction railheads and marshalling yards during trips listed under (1) and (2) above.

This variety of phases of empty stock working (trips or stabling periods) suggests a need for arriving at methods which permit a definition and appraisal of these different contingencies, and of the different combinations of these contingencies. It is, in other words, a question of finding a unit of measurement which will permit a global appreciation of the entire movement of empty stock, or at least that of the wagons forming part of the traffic serving the region itself.

It would also seem necessary to specify suitable working methods for the use of the executive organs responsible for the control of empty wagon movements. These executive organs (which may be located at the yards or at regional headquarters) must be in a position to keep a check on all the elementary phases of the use of the empty wagons placed at their disposal (trips and stabling periods, classified by the main types of wagons). Also at managerial level (regional and central headquarters), where supervisory functions are exercized, it must be possible to make use of global units of measurement in order to assess the utilisation of empty stock. It is therefore indispensable to establish the mathematical formulas required for the calculation of these units of measurement and to specify the methods by which the independent variables in these formulas are to be ascertained.

The method at present adopted for controlling the circulation of empty wagons consists, first of all, in ascertaining the numbers of empty wagons available and required, and in issuing appropriate instructions for the movement of empty wagons. These instructions are mostly confined to stating the number of empty wagons which, in a given time, must be moved from one region to an adjacent region without, as a rule, specifying the stations of destination; this simply amounts to a « launching », as it were, of empty wagons from one region to an adjacent one.

Not always are the empty wagons provided with allocation labels. The distribution of empty wagons is generally a matter for the executive organs, assisted somewhat indifferently, so it would seem, by the train working office which is more concerned with analysis and verification.

One feels the lack of a global unit of measurement for the efficiency of the utilisation of empty stock. The unit of measurement mostly used at present, and known as the coefficient of empty wagon circulation, W_v, is worked out from the following formula :

$$W_v = \frac{N_v}{U_{ch}} \text{ (days)},$$

where N_v represents the total number of empty wagons, whilst U_{ch} signifies the number of wagons loaded in the course of 24 hours. This coefficient can only apply to the railway network as a whole, without providing any useful data for the individual regions. Generally, it is rather unusual to analyze the periods of times during which the empty wagons are stabled in the course of the successive phases of their round-trip; nor, for that matter, is it usual to carry out a very thorough examination of the trips of empty wagons : flow diagrams of empty wagons are rarely plotted.

TABLE 1.

Railway Network		Average distance covered by loaded wagons (km)	Average distance covered by empty wagons (km)	Empty wagon kilometrage coefficient (α)	Wagon turn-round (days)
Germany	1956	193	91	0.472	4.35
	1957	196	93	0.475	4.76
Austria	1956	186	83	0.445	3.7
	1957	187	83	0.443	4.35
Belgium	1956	114	55	0.486	5.9
	1957	115	64	0.557	6.25
Spain	1956	299	107	0.356	9.1
	1957	503	110	0.364	9.1
France	1956	312	109	0.35	8.3
	1957	309	106	0.34	7.7
Great Britain	1956	145	62	0.424	12.5
	1957	144	61	0.425	12.5
Italy	1956	277	119	0.43	8.3
	1957	280	129	0.461	8.3
Japan	1956	299	77	0.26	3.2
	1957	300	77	0.256	3.14
Norway	1956	153	49	0.32	4.8
	1957	150	51	0.337	4.76
Poland	1956	228	98	0.44	5.16
	1957		99	0.43	5.06
Sweden	1956	243	81	0.335	5.6
	1957	236	87	0.37	5.57
Switzerland	1956	99	43	0.434	3.02
	1957	103	47	0.454	3.02
Turkey	1956	372	119	0.32	5.8
	1957	373	117	0.312	5.57

Table 1 illustrates the variations in the wagon turn-round (W) as well as those of the empty wagon kilometrage coefficient (α) (*), of the mean distances covered by loaded wagons (S_{ch}) and of the mean distances covered by empty wagons (S_v),

(*) Empty wagon kilometrage coefficient :

$$\alpha = \frac{\Sigma/ns/_v}{\Sigma/ns/_{ch}},$$

where $\Sigma/ns/_v$ signifies the wagon kilometrage of empty wagons, within the region during 24 hours, and $\Sigma/ns/_{ch}$ the corresponding kilometrage of loaded wagons.

for certain railway administrations during 1956 and 1957.

Table 2 shows the variations in the axle kilometrages of empty wagons ($\Sigma(ns)_v$ in axles-km per 24 hours, and those of the coefficient at empty wagon circulation (W_v) for the Polish State Railways (PKP) in 1956, 1957 and 1958.

TABLE 2.

Year	Axle kilometrage of empty wagons per 24 hours	Coefficient of empty wagon turn-round (days)
1956	8 463 462	1.16
1957	8 910 291	1.176
1958	8 990 206	1.264

Table 1 gives rise to the following conclusions :

1. If one adopts the following criteria :

— for the wagon turn-round :

$$W = 5 \text{ days};$$

— for the empty wagon kilometrage coefficient : $\alpha = 0.4$, the railway networks listed in Table 1 can be assigned to four groups :

a) working with $W < 5$ and $\alpha < 0.4$

b) working with $W < 5$ and $\alpha > 0.4$

c) working with $W > 5$ and $\alpha < 0.4$

d) working with $W > 5$ and $\alpha > 0.4$

The first group (*a*) includes the Japanese, Norwegian and Jugoslav railways, the second group (*b*) the Austrian, Swiss and German railways, the third group (*c*) the French, Spanish, Swedish and Turkish railways, and the fourth group (*d*) the British, Belgian, Italian and Polish railways.

2. By increasing the stabling time of the wagons at the yards (after completion of unloading) with a view to increasing the number of double loading operations, it is possible to effect savings in empty wagon kilometrage (expressed by a low value of α), and, at the same time, to obtain good results for the wagon turn-round, as is demonstrated by the example of the railways comprised in group (*a*).

3. Most of the railways in group (*d*) are in a position favourable to passing to group (*a*), since the mean distances covered by loaded wagons (S_{ch}) on the railways included in this group range from 150 km (Norway) to 300 km (Japan).

It is likely that in most cases, the main cause for a fairly poor utilisation of empty stock must be seen, not in the magnitude of the empty wagon kilometrage coefficient (α), but in the prolonged stabling of empty wagons at the unloading and loading yards and at the junction railheads and marshalling yards en route. It would appear that such prolonged stabling is due to an inadequate degree of flexibility in the empty wagon control organisation. In order to answer the question to what extent the unproductive trips of empty wagons must be regarded as the cause of the long turn-round times of empty wagons, and to what extent the lack of adequate organisation of wagon circulation is

to be held responsible, it is necessary to carry out a thorough examination of the operation of the system.

It is also important to ascertain the cost price (including the cost of track maintenance, the cost of traction, and of the traffic organisation) of the trips of empty wagons alone. In the case of the Polish Railways, for example, this cost amounts to 8 990 206 (*) × 0.366(**) = 3.25 million zlotys per day.

A reduction of the empty wagon kilometrage coefficient from 0.44 to 0.4, equivalent to a shift from group (*d*) to group (*a*), would enable the Polish Railways to effect a saving estimated at 10 %, i.e. 325 000 zlotys per day.

The following considerations deal with the theoretical principles and practical methods to be adopted in regard to the circulation of empty stock on railway networks. Their objective is to improve the economic efficiency of this circulation through achieving, if possible, the saving mentioned above.

1. THEORETICAL PRINCIPLES GOVERNING THE NATURAL CIRCULATION OF EMPTY WAGONS

1.1 Classification of the elementary movements.

It is well known that the wagon, in the course of its transport function, passes through turn-round cycles which consist, successively, of the loading operation, the trip in the loaded condition, the unloading operation and, possibly, the trip in the empty condition to the following loading yard.

The loading and unloading operations at the yards may cause there either a surplus of empty wagons (if the number of unloading operations exceeds that of loading operations) or a shortage of empty wagons (in the opposite case), or a state of equilibrium (if the number of unloading operations is equal to the number of loading operations). It is therefore necessary to despatch empty wagons from yards where they are surplus to those where they are in short supply.

In consequence, a heavy movement of empty wagons, moved in complete trains or otherwise, is encountered throughout the system, and has the effect of rendering operation more complicated. It is, however, possible to discern in this process numerous and greatly variegated « *elementary movements* » of empty wagons, a term which we shall apply to the despatch of empty wagons, separately or in groups, between two specific stations, adjacent to or distant from each other.

These movements are always controlled (*); they may be based on natural laws, or on relative priorities fixed by special freight transport agreements. We shall here leave these agreements out of account and confine ourselves, in the following considerations, to the study of the natural laws governing the circulation of empty wagons. Departing from this principle, we shall discuss certain conceptions with a

(*) From table 2.

(**) The cost per axle-kilometre of the trip of an empty wagon on the Polish Railways amounts to approx. 0.366 zlotys.

(*) This control consists in a deliberate intervention in the process of empty wagon circulation, on the strength of the knowledge of the magnitude of the relevant variables (e.g. loading demands) relating to the future.

view to determining a method for working out rational programmes for the circulation of empty wagons.

In general, a railway region cannot freely arrange the circulation of empty stock within its territory; sometimes, it is necessary to feed the yards within the region with empty wagons coming from outside (wagons which constitute « incoming traffic » for the region concerned); sometimes, it is necessary to export the surplus of empty wagons to other regions (« outgoing traffic »); sometimes, finally, the region must be crossed by flows of empty wagons coming from and going to different regions (« transit traffic »).

The obligations of each region, laid down with due regard to the general interest of the railway network at large, must be reflected in instructions issued to the inter-regional wagon exchange yards concerning the forwarding or reception of given numbers of empty wagons.

The phenomenon of the circulation of empty wagons within a region can be regarded as the resultant of the movements carried out, in numerous trips, by larger or smaller groups of empty wagons. These movements are themselves the result of the combination of numerous and diverse elementary movements of isolated empty wagons, or groups of wagons.

The elementary movements may be caused by two entirely independent reasons viz.

1. the need for carrying out a direct movement of empty wagons between yards in order to cover the loading requirements at one of these yards;

2. the need for carrying out a movement of the surplus of empty wagons, accumulating at certain yards, from one part of the region to another where a shortage of empty wagons is felt; this movement consists in working empty wagons between junction railheads and is based on the knowledge of loading requirements throughout the region.

Among the elementary movements belonging to the first of these categories, it is possible to distinguish between the following five types :

1. Movements carried out between two intermediate wayside railheads on the same section of line, e.g. between railheads 1 and 2 in figure 1;

2. Movements carried out between a wayside railhead and the junction railhead situated at the end of the section of line, e.g. between railheads 15 and F;

3. Movements carried out between a wayside railhead and a junction railhead situated outside the section of line to which the wayside railhead belongs, e.g. railheads 1 and F, or 6 and K;

4. Movements carried out between two wayside railheads on different sections of line, e.g. 5 and 10;

5. Movements carried out between two junction railheads, adjacent or otherwise, e.g. E and F, K and E, or K and L.

The elementary movements belonging to the second category represent a sixth type of elementary movement.

In keeping with the definitions outlined above, the movement from K to L, quoted as an example of a movement of type (5), represents transit traffic in respect of the region considered; the movement from K to E represents incoming traffic, whilst the movement from 6 to K, serving as an

example for a movement of type (3), represents outgoing traffic. All the other movements quoted as examples form part of the traffic local to the region surveyed.

The classification, outlined above, into six types of elementary movements is sufficiently detailed to enable us to continue with the examination of the problem.

greatest possible savings are effected. On the strength of these principles, it is possible to lay down two basic criteria for the natural circulation of empty wagons, viz. *the kilometrage criterion, and the wagon-hours criterion.*

The first criterion may be defined as follows :

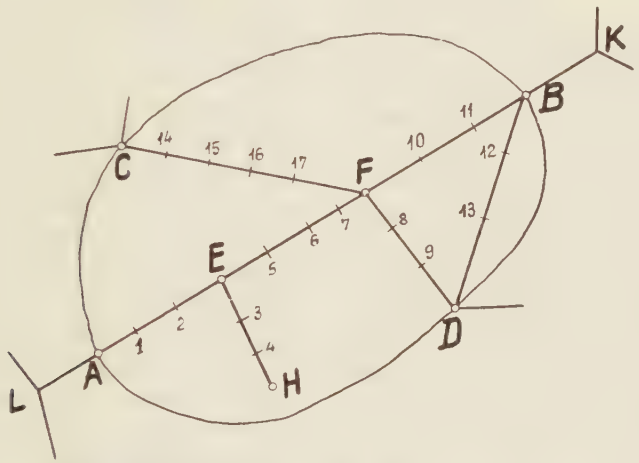

Fig. 1. — Railway region within the confines ABCD.

A, B, C, D = Inter-regional wagon exchange yards.
E, F = Junction railheads within the region.
K, L = Junction railheads in other regions.
H = Terminal railhead.
1, 2, 3 ..., 17 = Intermediate (wayside) railheads on the sections of line connecting the junction railheads.

1.2. Basic criteria for the circulation of empty wagons.

The organs responsible for controlling the circulation of empty wagons may, at their discretion, make use of all the types of elementary movements described above, provided that the loading requirements of all the yards within the region are fully covered, that the reception and forwarding of empty wagons at the inter-regional exchange yards is ensured, and that the the sum total of the movements of empty wagons indispensable for covering the loading requirements of the whole region and the demands arising from collaboration with the other regions of the network must be reduced to a minimum.

If k_p is the cost per axle-kilometre of empty wagon (comprising the cost of movement (*) only, such as the cost of

(*) On the Polish Railways, the present values of k_p and k_h have been calculated to amount to 0.366 and 0.8 zlotys, respectively.

track maintenance, cost of motive power, and cost of traffic organisation), and if $\Sigma(ns)_v$ is the total axle-kilometrage of empty wagons, the first criterion can be expressed by the condition :

$$k_p \cdot \Sigma(ns)_v \text{ minimum.}$$

The second criterion may be defined as follows :

the movements indispensable for covering the loading requirements of the whole region and the demands arising from collaboration with the other regions of the network must include a minimum of stabling of empty wagons at the loading yards or junction railheads of the region surveyed.

If k_h is the cost per wagon-hour (comprising exclusively the cost of depreciation maintenance and repair of the wagons) and if $\Sigma(nh)_v$ is the total number of wagon stabling hours, the second criterion can be expressed by the condition :

$$k_h \cdot \Sigma(nh)_v \text{ minimum.}$$

If the six types of elementary movements listed in Section 1.1 are studied with a view to meeting the second criterion in the best possible way, it will be seen that :

1. in order to achieve a reduction in the stabling time of empty wagons at the loading yards, the wagons should be removed as soon as possible;

2. in order to reduce the stabling time of empty wagons during their passage through junction railheads it is desirable to combine similar elementary movements so as to set up flows of empty wagons in sufficient numbers to make up whole trains;

3. it is desirable to move minor surplus numbers of empty wagons from wayside yards to the junction railheads at the end of the section of line so that, at the latter points, the wagons can be combined in sufficient numbers to make up whole trains;

4. it is highly desirable to make use of through movements;

5. it is desirable to despatch empty wagons coming from or destined for a given region in whole trains over the longest possible part of their itinerary.

The superiority of the movements of type (2) over those of types (3) and (4) is thus obvious in those cases where the number of empty wagons in a flow does not reach the number required to make up a whole train; it is also evident that, under similar conditions, movements of type (3) are superior to those of type (4).

Each elementary movement of empty wagons should, before being carried out, be subjected to a test with a view to ascertaining whether the economic conditions expressed by the two criteria are fulfilled. In the general case when one has the choice of two alternatives, I and II, it is necessary to verify the inequality :

$$k_p \cdot \Sigma(ns)^{I}_v + k_h \cdot \Sigma(nh)^{I}_v < k_p \cdot \Sigma(ns)^{II}_v + k_h \cdot \Sigma(nh)^{II}_v. \quad . \quad (1)$$

In the less complicated cases of elementary movements where the value of certain terms in formula (1) is zero, this inequality is simplified.

If it is, for example, desired with the aid of formula (1) to solve the problem of knowing whether, at railhead H (fig. 1), the stabling time of the surplus of empty wagons should be extended to the next loading operation or whether, on the contrary, these wagons should be for-

warded and the subsequent loading operations be left to empty wagons received later, it is possible to use a simplified version of formula (1) since (if the index I relates to the alternative of prolonged stabling of the empty wagons at railhead H) the term $k_p \cdot \Sigma(ns)^{I}_{v}$ is equal to zero. is possible to use a simplified version of formula (1) in the form

$$\Sigma(nh)^{I} < \Sigma(nh)^{II}$$

Finally, if it is desired to know whether it is preferable to convey n empty wagons from A to B (alternative I) or from A to C

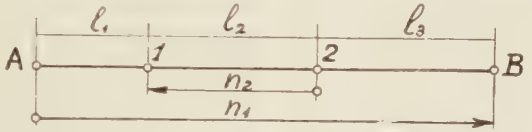

Fig. 2.

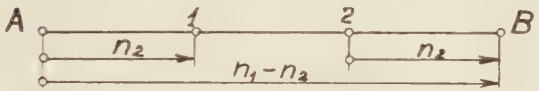

Fig. 2a

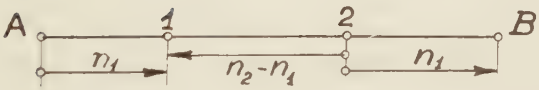

Fig 2b

Similarly, if it is desired to solve the problem of knowing whether, at the inter-regional wagon exchange yard A (fig. 1), the stabling of empty wagons destined to pass through the region from A to B should be prolonged with a view to forming whole trains which need not pass through the marshalling yards at E and F (alternative I), or whether the wagons should be despatched in small groups with the possibility of prolonged stabling at yards E and F (alternative II), the term $\Sigma(ns)_v$ is the same in both cases so that it (alternative II), it is obviously possible to use the simplified form of formula (1)

$$\Sigma(ns)^{I}_{v} < \Sigma(ns)^{II}_{v}$$

1.3. Unproductivity of counter-running movements.

Assume that a section of line A B contains two wayside yards 1 and 2 (fig. 2), and that a movement of n_1 empty wagons takes place from A to B, and a movement of n_2 empty wagons from yard 2 to yard 1.

By the criterion of minimum kilo-

metrage, the counter-running, on the trip from 1 to 2, of the flow of n_1 wagons and the flow of n_2 wagons is unproductive. In fact, if $n_1 > n_2$, yard 1 could be supplied with wagons taken from flow n_1, whilst the n_2 wagons at yard 2 and the remainder $(n_1 - n_2)$ of flow n_1 originating at A could be directed to B (fig. 2*a*). If, on the other hand, n_1 is smaller than n_2, it would be necessary, after having supplied yard 1 with n_1 wagons from yard A, to despatch $n_2 - n_1$ wagons from yard 2 to yard 1 and to direct the remainder, i.e. $n_2 - (n_2 - n_1) = n_1$ wagons, from yard 2 to yard B (fig. 2*b*).

The wagon kilometrage as shown in figure 2 amounts to :

$$\Sigma(ns)^{I}_{v} = n_1(l_1+l_2+l_3)+n_2\ l_2 \quad \text{(wag.-km)}$$

The wagon kilometrage as shown in figure 2*a* will amount to

$$\Sigma(ns)^{II}_{v} = n_2\ l_1+n_2\ l_3+(n_1-n_2)\ (l_1+l_2+l_3)$$
$$= n_1 l_1+(n_1-n_2)l_2+n_1\ l_3 \quad \text{(wag.-km)}$$

Finally, the wagon kilometrage as shown in figure 2*b* will amount to :

$$\Sigma(ns)^{III}_{v} = n_1 l_1+(n_2-n_1)l_2+n_1 l_3 \text{ (wag.-km)}$$

One thus obtains :

$$\Sigma(ns)^{I}_{v} - \Sigma(ns)^{II}_{v} = 2\ n_2\ l_2 \quad \text{(wag.-km)}$$

and

$$\Sigma(ns)^{I}_{v} - \Sigma(ns)^{III}_{v} = 2\ n_1\ l_2 \quad \text{(wag.-km).}$$

The counter-running of the trips of empty wagons thus gives rise to an unproductive kilometrage which assumes the value of twice the product of the number of wagons of the smaller flow and the length (in kilometres) of the section common to both movements.

1.4. **Wagon potential of a yard.**

It is now proposed to introduce the conception and term of the wagon potential of a yard and to define it as the capacity of a yard in regard to the exchange of empty wagons at a given moment. The wagon potential will be a number representing the quantity of wagons available for exchange; this number may be positive or negative.

We shall thus denote the capacity, e.g. of yard A, of despatching empty wagons after having met its own loading demands by the number $+ U_A$, and the shortage of empty wagons, e.g. at yard B, after having unloaded its wagons, by the number $- U_B$. We shall talk of the potential $+ U_A$ in the first case, and of the potential $- U_B$ in the second case. Those yards where there is neither a surplus nor a shortage of wagons will be in a neutral condition, their wagon potential being zero.

In order to determine the wagon potentials of a yard, we may now examine a yard N which has the following characteristics during a 24 hour period :

- loading U_{ch} wagons,
- unloading U_d wagons,
- double loading operation U_{dch} wagons,
- total number of empty wagons at the beginning of the 24 hours period : U_1 wagons,
- number of empty wagons taken out of commission (due to damage) during a 24 hour period : U_2 wagons.

At the end of the 24 hour period, the exchange capacity of yard N can be calculated from the formula :

$$U_N = (U_1 - U_2) + (U_d - U_{dch}) - (U_{ch} - U_{dch})$$
$$= U_1 - U_2 + U_d - U_{ch} \text{ (wag. per day) (2)}$$

If the value of the second term of equation (2) is positive, yard N will be capable of supplying U_N empty wagons and would therefore have a positive potential : U_N. If the value of the second term of equation (2) is negative, the wagon potential of yard N will be negative.

The first element of the second term of equation (2), amounting to $(U_1 - U_2)$, represents the change brought about in the number of empty wagons; the second element $(U_d - U_{ch})$ represents that number of unloaded wagons for which no new loading could be found so that they are surplus, whilst the third element $(U_{ch} - U_{dch})$ represents the number of empty wagons still required after all the unloaded wagons have been used.

Each unloaded wagon is not necessarily re-loaded at the same yard, in spite of the high demands of that yard. In fact, it is necessary to distinguish, within the same general type of wagon, several different categories characterized by special features which, in practice, preclude complete interchangeability. The inequality $U_d > U_{dch}$ will therefore apply to the majority of yards.

By means of formula (2), it is possible to determine for all railheads (wayside as well as junction railheads) the wagon potentials relating to their own loading requirements. It will be seen that these do not depend on the number of double loading operations, U_{dch}.

In determining the wagon potential for a junction railhead, it is also necessary to take into account the part played by the railhead in handling empty wagons of the intermediate wayside yards served. The junction railhead will receive ΣU_i wagons in 24 hours from the wayside yards, and will forward to these yards ΣU_e wagons in 24 hours.

The wagon potential of the junction railhead, depending firstly on the own loading requirements of that yard, and secondly on the demands of the wayside yards served by it, is given by :

$$U_K = U_1 - U_2 + U_d - U_{ch} + \Sigma U_i - \Sigma U_e \text{ (wag. per day)}. \quad (3)$$

Each inter-regional wagon exchange yard receives and forwards certain numbers of empty wagons as a result of the envisaged collaboration of the region with the network at large.

If U_p is the number of empty wagons forwarded to points outside the region, and U_r the number of empty wagons received as part of this operation in the course of 24 hours, it is possible to calculate, by means of a suitably expanded version of formula (3), the wagon potential U_e of the exchange yard which, in addition, serves as a loading and unloading yard (U_{ch} and U_d) and may also take part in handling the traffic, for wayside yards inside the region, (ΣU_i and ΣU_e); this potential will thus amount to :

$$U_e = U_1 - U_2 + U_d - U_{ch} + \Sigma U_i - \Sigma U_e + U_r - U_p \text{ (wag. per day)} \quad (4)$$

With the aid of the notion of the wagon potential as defined above, it is possible to formulate the following principles relating to the circulation of empty wagons :

1. If the work within the region as well as the duties resulting from the collaboration of the region with the network at large are carried out correctly, the sum total of the wagon potentials of the junction and

wagon exchange railheads of the region is equal to zero :

$$\Sigma U_K + \Sigma U_c = 0.$$

2. If the movement of empty wagons between two yards is justified by the requirements of one of them (types of movements 1, 2, 3, 4 and 5 listed in Section 1.1), the circulation of empty wagons must take place from the yard with positive potential to the yard with negative potential. The volume of the flow of empty wagons (e.g., in the case of one yard with positive potential feeding several yards with negative potential) must not, however, exceed the absolute value of the smallest potential.

3. The movement of empty wagons between two yards, resulting from the needs of a third yard (movement of type 6 in Section 1.1) is carried out independently of the sign and the magnitude of the potentials of these two yards.

The wagon potentials of the yards are not constant even if one considers the same period of a given cycle (e.g. a certain day of the week), as the independent variables contained in formulas (2), (3) and (4) are the functions of numerous parameters which vary in the course of time, their magnitude most frequently being determined at random by the momentary traffic requirements.

Therefore, if the circulation of empty wagons is to be based on the wagon potentials, it is desirable to ascertain their magnitude not only for the 24 hour period envisaged but also for the following 24 hour periods, as the programme drawn up at a given moment must take the prospective wagon loading and unloading operations into account.

1.5. Determining the probable wagon potential of a yard.

Consider a yard M which has a wagon potential U. The magnitude of this potential can readily be calculated by means of formulas (2), (3) or (4) on the strength of the statistic data of their independent variables for each day of the week over a period containing any number of weeks, n.

The successive values of the wagon potential can be recorded as shown in the table below :

Mondays . . .	U'_1,	U'_2,	U'_3	.... U'_n
Tuesdays . . .	U_1^{II},	U_2^{II},	U_3^{II}	.... U_n^{II}
Wednesdays .	U_1^{III},	U_2^{III},	U_3^{III}	.... U_n^{III}
. . . . .				
Sundays . . .	U_1^{VII},	U_2^{VII},	U_3^{VII}	.... U_n^{VII}

We shall now try to determine the probable values of the wagon potential U for each day of the week, as the probability value p has not been determined so far.

Suppose that, for any one day of the week, used as an example, the potentials U calculated by the above-mentioned method on the basis of data obtained over a period of n weeks form a series of numbers :

$$U_1, U_2, U_3, U_4 \ldots\ldots\ldots U_n$$

In this series, the same numbers may be recurring.

Assume that :

the number U_1 appears K_1 times
the number U_2 appears K_2 times
the number U_3 appears K_3 times, and
the number U_n appears K_n times
so that, obviously, $K_1+K_2+K_3+\ldots K_n$
$\Sigma K \quad n.$

The probability of obtaining for U the value U_1 is thus :

$$p_1 = \frac{K_1}{\Sigma K};$$

the probability of obtaining for U the value U_2 is :

$$p_2 = \frac{K_2}{\Sigma K};$$

the probability of obtaining for U the value U_3 is :

$$p_3 = \frac{K_3}{\Sigma K};$$

and the probability of obtaining for U the value U_n is :

$$p_n = \frac{K_n}{\Sigma K}.$$

of these potentials can vary for a given probability P, laid down beforehand.

Making use of the fact that the probability of a sum of elements is equal to the sum of their probabilities, we extract from the table above a certain number of probability values p so that their sum is equal to the predetermined probability P, $\Sigma p = P$. As the values of the potentials U corresponding to the chosen probabilities p are known, we are thus able to determine the limits U_{max} and U_{min} within which the potential U will be contained with a probability P.

It is obvious that the probabilities p must be so chosen that the difference between U_{max} and U_{min} is as small as possible.

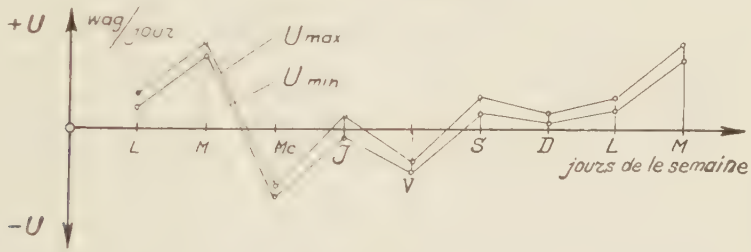

Fig. 3.

N. B. — Jours de la semaine = days of the week. — Wag./jours = wagons per day.

If we now, commencing with the highest value, arrange the probabilities p and the corresponding values of the potentials U in the form of a series, we may assume that this series, for the case considered, takes the following form :

p_3 for U_3 (maximum probability),

p_7 for U_7,

p_4 for U_4 and U_9,

p_5 for U_5 and U_8 (minimum probability).

As we now know the probabilities of the occurrence of the potentials U, we can calculate the limits within which the values

It will then be possible, for a given yard, to plot a graph showing the probable values of the wagon potentials as a function of time for the period of one week. These values will be contained between the U_{max} and U_{min} curves with a probability P. Figure 3 provides an example of such a graph.

1.6. Working out the theoretical programme for the circulation of empty wagons.

On the strength of :

— the basic criteria of the movement of empty wagons, i.e. the kilometrage cri-

terion and the criterion of wagon hours, and the resulting conclusions (Section 1.2.);

— the principles governing the circulation of empty wagons which permit the determination, on the basis of the wagon potentials of the yards, of the volume and direction of the flows of empty wagons (Section 1.4.);

— the method of determining the probable wagon potentials (Section 1.5.),

and also taking into account the results of Section 1.3. concerning the unproductivity of counter-running movements of empty wagons, it is possible to work out a theoretical programme for the circulation of empty wagons in a region with a probability P which is known, and fixed beforehand. This programme takes into account the data relating to the specific days of the week, and is repeated cyclically over a period of one week.

The introduction of the values U_{max} and U_{min} of the wagon potentials into the calculations gives rise to two versions of the theoretical programme for the circulation of empty wagons.

In the minimum version, which is based on the smallest numbers of wagons in circulation, this programme may serve for the compilation of the timetables of regular trains of empty wagons (possibly working at certain days of the week only); the maximum version, on the other hand, will supply data concerning the need for running optional additional trains.

Such a programme, which must be valid for a sufficiently long period (six months or a year, depending on the seasonal variations in traffic) would enable the movement plan (*) of empty stock to be placed on a much more regular basis than that which is possible with present-day empiric methods; it would ensure the observation of the wagon hours criterion under the best possible conditions and would, finally, ensure a faster wagon turn-round.

If one adopts the rule of determining the regular movements of empty wagons, on the one hand, on the *minimum value* of the wagon potential of the forwarding yard (positive potential) and, on the other hand, on the *mean value* of the wagon potential of the receiving yard (negative potential), one will obtain, distributed over the whole region, a certain number of empty wagons without immediate destination, available to cover possible demands. These wagons constitute a « *compensation pool* ».

Similarly, it appears necessary to provide, within the region, a *reserve pool* of empty wagons amounting to γ. ($\Sigma U_{max} - \Sigma U_{min}$) where ΣU_{max} and ΣU_{min} are the sums of the maximum and minimum values, respectively, of the wagon potentials of all the yards in the region examined, whilst γ is a coefficient to be determined on the strength of statistical research.

Statistical research within the region will also be needed to determine the yards (junction railheads, in principle) best suited to serve as centres for the wagon pool mentioned above, taking into account, at the same time, the location of the empty wagon compensation pool (also, in principle, located at junction railheads) as well as the geographical situation of the yards with positive and negative wagon potential, respectively.

(*) « Movement plan » is here taken to mean the entire range of operations affecting the composition as well as the itineraries of the trains; this notion is thus used in a wider sense than that of « allocation ».

In order to work out the theoretical programme for the circulation of empty wagons in the region surveyed, one might proceed in the following manner, dealing separately with each main type of wagons.

1. On the strength of the probabilities method, separately for each day of the week, one determines the minimum and maximum wagon potentials U_N of all the wayside yards of the region examined, the potentials U'_K (equal to U_K if $\Sigma U_i = \Sigma U_e = 0$) of all the junction railheads in the region, and finally the potentials U'_e (equal to U_e if $\Sigma U_i = \Sigma U_e = 0$) for all the inter-regional wagon exchange yards (border stations).

2. One then calculates the sums of U_{Nmin} and U_{Nmax} for each day of the week, for all the wayside yards of the different sections of line.

3. One records the two values of the potentials U'_K and U'_e for the junction railheads and inter-regional wagon exchange yards as well as the potentials ΣU_N of the sections and thus obtains, for each day of the week, a synopsis of the geographical distribution of the potentials (fig. 4).

4. In keeping with the principles formulated in Section 1.4., one then determines the flows of empty wagons, using for the yards (or sections) with positive potential the minimum potential of the day n, and for the yards (or sections) with negative potential the mean potential of the following day $(n + 1)$. One thus obtains, for the different sections, the *natural directions of*

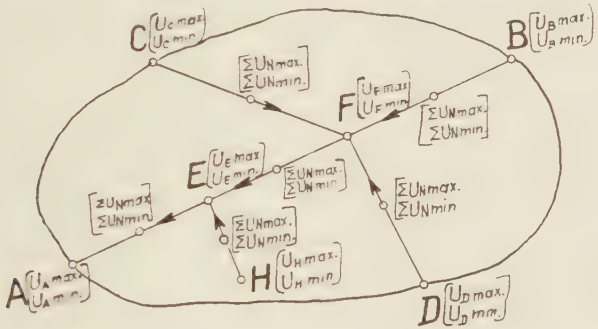

Fig. 4.

the circulation of empty wagons, represented by the arrows in figure 4.

5. Once the natural directions of flow are established, which will enable us to avoid unproductive trips resulting from counter-running movements, it is possible to establish, for each section of the region surveyed, and for the duration of a week, a diagram (fig. 5) illustrating the movement of empty wagons. With the aid of this diagram, one can determine, for each of the railheads at the end of the section considered (A and B in fig. 5), the number of empty wagons to be received (U_i) and the number of empty wagons to be forwarded (U_e) in order to serve this section.

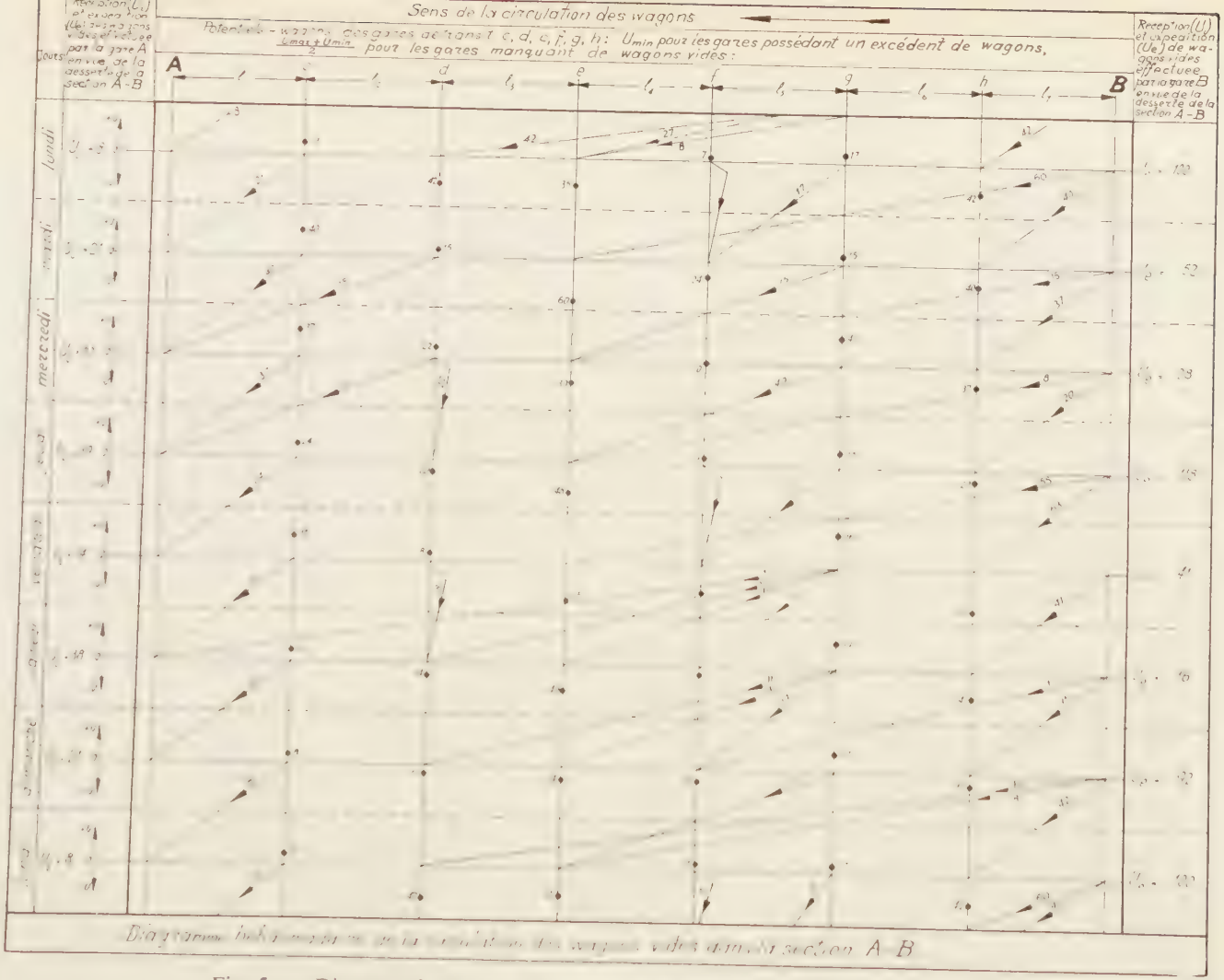

Fig. 5. — Diagram of the weekly movement of empty wagons over the section A-B.

Explanation of French wording :

Jours : lundi, mardi, mercredi, jeudi, vendredi, samedi, dimanche, lundi = days : Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday, Monday. — Reception (U_r) et expedition (U_e) des wagons vides effectuee en vue de la desserte de la section A-B = numbers of empty wagons arriving at junction railhead A (U_r), and leaving from junction railhead A (U_e) for the service of section A-B. — Sens de la circulation des wagons = direction of wagon movement. — Potentiels - wagons des gares de transit c, d, e, f, g, h . U_{min} pour les gares possedant un excedent de wagons, $\frac{U_{max} - U_{min}}{2}$ pour les gares manquant de wagons vides = wagon potentials of wayside railroads c, d, e, f, g, h . U_{min} for railroads having a surplus of wagons, $\frac{U_{max} + U_{min}}{2}$

Obviously, this diagram must be based on the U_{min} value of the day n for the yards with positive potential, and on the mean value between U_{min} and U_{max} of the day $(n + 1)$ for the receiving yards.

As far as the compensation and reserve pools of empty wagons are concerned, referred to earlier on, these should be set up, in principle, either at the junction railheads or at the inter-regional wagon exchange yards.

6. Once the characteristic values U_i and U_e have been established, with the aid of the diagrams of the separate sections, for the railheads at the ends of the sections (for each day of the week), it is possible to calculate, with the aid of formulas (3) and (4), the minimum and maximum values of the wagon potentials of each junction railhead U_K and each inter-regional wagon exchange station U_c, for each day of the week.

7. We then draw up the regional distribution diagrams on the basis of the minimum and maximum values of the wagon potentials U_K and U_c calculated as shown under (6) above, and also enter on them the data concerning the compensation and reserve pools of empty wagons.

These diagrams must be drawn up for each day of the week so that seven of them are required. The map relating to the nth day of the week must be based on the minimum values of the positive potentials of the day $(n - 1)$, and on the mean values of the negative potentials of the day n.

8. In keeping with the principles outlined in Section 1.4., we determine, within the region, the flows of empty wagons by making use, at the same time, of the compensation and reserve pools of empty wagons; we thus obtain the theoretical programme for the circulation of the flows of empty wagons, defined by their directions and their volumes, in the form of diagrams illustrating the daily variations of the weekly cycle.

9. With the aid of these diagrams, it is possible to prepare the « movement plan » of empty wagons (in the sense explained earlier on) and to calculate the wagon kilometrage of the indispensable movements.

These theoretical considerations on the compilation of the programme for the circulation of empty wagons within the region should be accompanied by the following remark. The application of the speculative method, here outlined, cannot go beyond a certain point. Beyond that point, it must be replaced by a practical method. It is in fact possible to go as far as point (6), including the strict procedure described above. In contrast, it will be desirable, in practice, to leave to the control agencies (responsible for the distribution of rolling stock) a degree of discretion in regulating the circulation of empty stock between the junction railheads and the wagon exchange stations of the region considered.

Provided that the conditions imposed by the criteria of minimum kilometrage and minimum number of wagon hours are observed, the circulation of empty wagons may either be organized with the aid of the method outlined above, based on the determination of the data on a probability basis and on the compilation and use of a cyclic weekly programme for the movement of empty wagons, with a minimum degree of direct intervention on the part of the control agency; alternatively, the

values of the wagon potentials might be ascertained directly by means of electronic units such as data processing machines, so that the stages mentioned above are replaced by a method of control based on calculation.

Theoretically, it is no doubt possible to resort to combined methods which are probably valuable in those cases where the data collecting and processing equipment available to the railway administration is relatively modest.

It should also be noted that it is possible, with the aid of the theoretical considerations outlined above, and with the aid of the conclusions resulting from them, to carry out, in a systematic manner, *a critical analysis and supervision of the actual circulation of empty stock over a given period of time* under known conditions of movement organisation.

For this purpose, it is necessary to prescribe :

1. the method of ascertaining and recording the numbers and itineraries of the individual flows of empty wagons passing over the sections of the railway network,

2. the method to be adopted in analyzing the data recorded in the way mentioned under 1) above, and

3. the method to be adopted in determining, subsequently, the best modifications to be applied to the flows of empty wagons as regards the choice of itineraries and the volume of wagon flows.

2. DETERMINING THE ITINERARY AND VOLUME OF FLOWS OF EMPTY WAGONS. ANALYSIS OF THE CIRCULATION OF EMPTY STOCK.

The method here proposed aims at solving the following problems :

— to ascertain the kilometrages of empty wagons within the territory of the railway region examined, by ascertaining the itineraries and volumes of the individual flows of empty wagons, as well as the unproductive counter-running flows of empty wagons;

— to tackle the question of an efficient organisation of the circulation of empty wagons.

This approach calls first of all for a suitable method of measuring the volumes and itineraries of the flows of empty wagons in the region considered.

The survey period adopted for this method is the ten-day period. Because of the inherent technical difficulties, it is not recommended to use a period of 24 hours, though this would lead to more precise results.

2.1. Survey method.

During the survey period, all the yards of the railway system of the Administration concerned are required to label (*) the empty wagons, on departure after unloading.

These labels must show, in a clearly legible form, the name of the forwarding yard.

With the aid of these labels, the staff required to prepare the « train sheet » will record the names of the stations from which the empty wagons have come.

The yards of the region concerned are required to remove these labels at the moment when the empty wagon, having arrived at the station of destination, is about to be loaded. The type of wagon

(*) This remark applies to those Administrations which do not normally use labels for their empty wagons.

should be recorded on the labels thus removed (where such identification has not already been made possible).

The labels thus collected in (for each ten-day period) are forwarded by the railheads to the survey centre. The railheads are required to communicate the number of wagons loaded and the number of wagons unloaded (classified by type of wagon) for each ten-day period.

The inter-regional wagon exchange yards (re-forwarding and reception yards) of the region concerned are required to forward to the survey centre, at the end of each ten-day period, the data concerning the exchange of empty wagons as well as the duplicates of the train sheets relating to trains leaving the region.

The Survey Centre is able to ascertain the volume of the incoming traffic and the traffic local to the region concerned, since the forwarding yard is shown on the label, and the yard of destination is the one which forwards the labels to the Centre.

With the aid of the duplicates of the « train sheets », the survey centre is also able to determine the magnitude of the outgoing traffic and transit traffic of the region concerned since the yard from which the empty wagon has been despatched is shown in the train sheet whilst the wagon exchange yard at which the wagon leaves the region, is the yard which forwards the « train sheet » to the Survey Centre.

These data enable the survey centre to classify and record the individual flows of empty wagons within the region in special basic data sheets (fig. 6).

It is desirable to prepare these data sheets for each ten-day period, and for each of the major types of wagons, i.e.

— covered wagons,
— high-sided open wagons,
— flat wagons,
— special wagons, i.e. all other wagons,

since, in studying the circulation of empty wagons, it is necessary to divide the latter into, at least, these four groups.

The classification of the wagon flows may be carried out either by machine or by hand. The order in which the names of the yards are entered in the sheet should make it easy to ascertain from the sheet the different categories of traffic; thus, the inter-regional wagon exchange yards (yards A, B, C, D ... in fig. 6) should be entered first, before entering all the other railheads (1, 2, 3, 4, etc.) of the region concerned.

The sheets thus prepared for each major wagon type and for each ten-day period indicate the volumes (in wagons per ten-day period) of the flows of empty wagons circulating in the region concerned in all possible relations.

To arrive at an estimate of the error liable to affect the survey, the following procedure might be adopted : the data provided by the inter-regional wagon exchange yards in regard to the exchange of empty wagons carried out by them can be compared with the results calculated from the basic data sheets (fig. 6), as follows :

— the sum of the number of transit and outgoing wagons worked out from basic data is compared with the number of wagons shown by the exchange yards to have left the region;
— the sum of the numbers of transit and incoming wagons worked out from the basic data sheet is compared with the number of wagons shown by the ex-

To rail-heads / From rail-heads	A	B	C	D	E	F	1	2	3	4	5	6	7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	Total wagon move-ments
A																																
B																																
C	Transit traffic													Incoming traffic																		
D																																
E																																
F																																
1																																
2																																
3																																
4																																
5																																
6																																
7	Outgoing traffic													Traf. loc. to the reg.																		
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.																																
.																																
.																																
.																																
.																																
Total																																

Fig. 6. — Basic data sheet of wagon circulation.

change yards to have entered the region.

2.2. Transformation and utilisation of the survey results.

2.2.1. *Flow diagrams of empty wagons.*

The basic data sheets (fig. 6), compiled directly on the basis of the survey results, cannot easily serve as means of assessing the efficiency of the organisation of the empty wagon flows (wagon hours criterion) or of detecting unproductive trips (kilometrage criterion), as these two problems must be examined with the aid of geographical diagrams.

The data contained in the basic data sheets must therefore be processed and represented in the form of flow diagrams showing the user of the different sections of the railway network, with given departure and destination points. If there is more than one possible itinerary between the given stations of origin and destination, it is necessary to choose the most likely route, which calls for a good knowledge of traffic conditions in the region concerned. In this way, one obtains *flow diagrams depicting the flows of empty wagons* (fig. 7) on the different sections of the railway network of the region.

In order to show up the counter-running trips of empty wagons, these diagrams must be plotted separately for each major type of wagon (covered, high-sided open, flat and special wagons); they might also be plotted either separately for each category of traffic (transit, incoming, outgoing, local), or by grouping certain categories of traffic together.

In choosing the best method of plotting the flow diagrams, one must be guided by the usefulness of these diagrams in appraising the efficiency of the organisation of the flows of empty wagons : in view of the great importance, to the notion of a « movement plan », of the problem which consists in accelerating as much as possible the cross-regional trips of those empty wagons which are surplus to re-loading requirements, and in view of of the fact that the transit wagons undoubtedly form part of that surplus whilst the incoming and outgoing wagons, taken together, constitute a certain fraction of that surplus, it is useful to plot the flow diagrams of empty wagons separately for transit traffic, for incoming and outgoing traffic, and for traffic local to the region.

It is relevant to point out that the proposed basic data sheets (fig. 6) permit a distinction between all these wagon flows.

It is therefore desirable to plot, for the region surveyed, a total of $4 \times 3 = 12$ flow diagrams of empty wagons for each survey period (ten-day period).

2.2.2. *Direct utilisation of the flow diagrams of empty wagons.*

Thus conceived, these flow diagrams clearly indicate :

— the volume and itinerary of transit traffic (across the region concerned) of empty wagons which will permit, from the outset, an appreciation of the possibility of forming whole trains of empty transit wagons in order to obtain their quickest transfer across the region without passing through the marshalling yards;

— the volume and itinerary of incoming and outgoing wagons, which will permit an instant appreciation of the pos-

Fig. 7. — Flow diagram of empty wagons.

sibility of forming whole trains of empty incoming and outgoing wagons and will also, in cases where the flows of incoming and outgoing empty wagons are found to pass over the same sections or through the same points, reveal the possibility of treating a certain additional number of empty wagons as transit traffic across the region concerned;

— the volume of the empty wagon flows in local traffic, which will permit an instant appreciation of the possibility of forming them into whole trains.

As already mentioned, the flow diagrams of empty wagons depict the flows surveyed during a ten-day period, instead of a period of 24 hours. Therefore, though revealing the existence of unproductive counter-running of empty wagons, they do not directly show up the wholly wasteful counter-running trips. It may well happen that, in the course of short periods of time (24 hours), certain trips, carried out over limited distances in order to cover the immediate needs of wayside yards situated between two junction railheads, must be regarded as necessary trips although they appear to be unproductive when seen on the large canvas of a ten-day period.

As we are unable to study this problem more closely without studying the position (in terms of their wagon potential) at all yards as a function of time, it is necessary to distinguish — and this distinction is also in keeping with the importance of the problem — between two types of counter-running of empty wagons among those revealed by the flow diagrams.

1. Counter-running encountered on certain sections of line which is undoubtedly unproductive, but probably unavoidable in those cases where reliance is placed exclusively on the practical method of controlling the circulation of empty wagons needed for covering the loading requirements of the wayside yards of the sections;

2. Counter-running, encountered over the whole length of sections between two junction railheads, of flows of empty wagons representing the movement between certain junction railheads of certain surplus numbers of empty wagons; such counter-running is not only likewise *unproductive but, at the same time, probably unnecessary.*

We shall therefore define and calculate, in terms of wagon kilometres, directly from the flow diagrams of empty wagons, first of all the kilometrages involved in the two types of counter-running together, $\Sigma(ns)_s$, and then, by the method outlined in Section 2.2.3. below, the distances involved in counter-running of the second type, $\Sigma(ns)_k$. This will, without any ambiguity, also permit the determination of the kilometrages involved in counter-running of the first type : $\Sigma(ns)_n = \Sigma(ns)_s - \Sigma(ns)_k$.

2.2.3. *Definition of the $\Sigma(ns)_k$ kilometrages.*

Consider a flow of empty wagons of the same type passing over a section I-II of the flow diagram of empty wagons (fig. 8).

As figure 8 shows, the loading requirements of the wayside yards on section I-II have been covered partly by a flow of empty wagons in the direction from I towards II, furnishing yard (*a*) with ($U'_1 - U'_2$) wagons and yard (*c*) with ($U'_3 - U'_4$) wagons, and partly by a flow of empty wagons in the direction from II

towards I, furnishing yard (*b*) with ($U''_3 - U''_2$) wagons.

Suppose that, in the most unfavourable case, the demand for ($U'_1 - U'_2$) wagons at yard (*a*) and the demand for ($U' - U'_4$) wagons at yard (*c*) arise simultaneously. If such a contingency should also coincide with the absence of empty wagons available at (*b*) (direction I-II), it must be admitted that, in order to cover the loading requirements of the wayside yards of the section concerned, a total of $U'_1 - U'_2 + U'_3 - U'_4$ wagons would have to be despatched from yard I.

The flow of wagons despatched from yard I in order to cover the requirements of the wayside yards of section I-II will therefore be represented, in figure 8, by the hatched area whilst the surplus flow of empty wagons flowing from I towards II will amount to :

$$N_1 = U'_1 - (U'_1 - U'_2 + U'_3 - U'_4) - U'_2 - U'_3 - U'_4 \quad \text{(wag.)}$$

By applying the same reasoning to the direction from II to I, the surplus flow of empty wagons can be defined as

$$N_2 = U''_4 - U''_3 + U''_2 \quad \text{(wag.)}$$

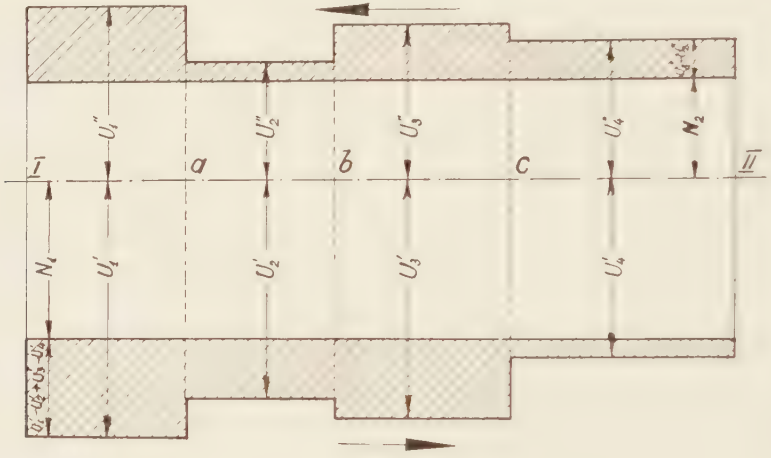


Fig. 8.

I and II = Terminal railheads of the section.
a, *b*, *c*, *d* = Intermediate (wayside) railheads of the section.
U'_1 , U'_2 , U'_3 , U'_4 = Numbers of empty wagons between wayside railheads, moving in the direction from I to II.
U''_1 , U''_2 , U''_3 , U''_4 = Numbers of empty wagons between wayside railheads, moving in the direction from II to I.

The flow of empty wagons likely to be wastefully counter-running on section I-II will therefore amount to N_2, if N_2 is smaller than N_1, or to N_1, if N_1 is smaller than N_2, i.e. to the smaller one of the surpluses of empty wagon flows passing over the section concerned.

2.2.4. *Calculation of the empty wagon kilometrages* $\Sigma(ns)_p$ *incurred in order to cover the loading requirements of*

Working Sheet No. 1	Numbers and kilometrages of empty wagons moving over the individual sections of line, taking into account the loading requirements of the wayside railheads

Sections of line as defined by their terminal railheads		Type of wagon :			Survey period :					
		Flows of empty wagons forming part of the traffic local to the region. — Data based on the flow diagrams.			Flows of empty wagons forming part of the incoming and outgoing traffic. — Data based on the diagrams.			Total		
		Numbers of wagons		Wagon kilometrages	Numbers of wagons		Wagon kilometrages	Numbers of wagons		Wagon kilometrages $\Sigma(ns)_p$
Terminal railheads of the section :		imported for the section	exported for the section		imported for the section	exported for the section		imported for the section	exported for the section	
		railhead I / railhead II			railhead I / railhead II			railhead I / railhead II		
I	II									
1	2	3	4	5	6	7	8	9	10	11
1										
2										
3										
4										
5										
etc										

Fig. 9.

wayside yards; calculation of the surplus wagon kilometrages $\Sigma(ns)_t$ *on the sections, and calculation of the wagon potentials of the yards.*

Taking into account the conclusions reached in the preceding section, it is desirable to make use of two types of survey forms in which the data obtained from the flow diagrams can be entered.

These forms must permit the calculation of the empty wagon kilometrages, $\Sigma(ns)_p$, as well as of the kilometrages $\Sigma(ns)_t$ referred to in the heading of the present Section.

The flow diagrams of empty wagons have been plotted separately for traffic local to the region and for incoming and outgoing traffic, even though these flows must be studied together. The purpose of the forms is therefore to provide a synopsis of the data concerned.

In order to determine the optimum variations of the movement plan of empty wagons (cf. the following Section, 2.2.5.), it is obviously necessary to use the data relating to the empty wagons introduced into the particular sections in order to cover the loading requirements of the wayside yards (e.g., in fig. 8, for the direction from I towards II, the volume of $U'_1 - U'_2 + U'_3 - U'_4$ wagons and, for the direction from II towards I, the volume of $U''_3 - U''_2$ wagons), as well as the data relating to the empty wagons withdrawn from the section (e.g., in fig. 8, for the direction from I towards II, the volume of $U'_4 - N_1$ wagons and, for the direction from II towards I, the volume of $U''_1 - N_2$ wagons). It is therefore indispensable that these data, too, should be entered in the forms concerned, after they have been converted into wagon potentials for the junction railheads.

Form N_1 will show, for each individual section, the number of imported and exported wagons which will enable the loading requirements of the wayside yards to be covered and also the direction of these movements. It is therefore also possible to determine the part played by the railheads at the ends of the section in feeding the wayside yards with empty wagons.

Column 11 of form N 1 indicates the kilometrage $\Sigma(ns)_p$ of empty wagons in the individual sections, incurred to cover the loading requirements of the wayside yards.

Column 11 of form N 2 indicates the kilometrage of counter-running and probably wasteful trips of empty wagons, $\Sigma(ns)_k$. The sum of the data extracted from columns 7 and 8, multiplied by the length of the section in kilometres, is equal to the kilometrage $\Sigma(ns)_t$ of empty wagons passing in transit over the sections of the region concerned.

The sum of $\Sigma(ns)_p$, obtained from form N 1, and of $\Sigma(ns)_t$ yields the total kilometrage $\Sigma(ns)_o$ of empty wagons incurred on the sections of the region studied.

2.2.5. *Method of optimizing the movement plan of empty wagons.*

The preceding Sections have yielded information on the kilometrages of empty wagons incurred in the region concerned as well as on the method of organising the trips. We are thus able to pass on to the problem of optimizing the movement plan of empty wagons. The problem consists in finding, while fully ensuring the loading requirements of the region studied, the optimum composition of the flows as well

Working Sheet N 2		Numbers and kilometrages of empty wagons counter-running on the individual sections									
Sections of line as defined by their terminal railheads		Type of wagon :						Survey period :			
		Data based on the flow diagrams of empty wagons forming part of the traffic local to the region		Data based on the flow diagrams of empty wagons forming part of the incoming and outgoing traffic of the region		Sum of these three traffic categories		Unproductive counter-running			Wagon kilometrages $\Sigma(ns)_t$
Terminal railheads of the section :		Numbers of surplus empty wagons departing from railheads :		Numbers of surplus empty wagons departing from railheads :		Numbers of surplus empty wagons departing from railheads :		Number of wagons	Length of sections in kilometers	Wagon kilometrages $\Sigma(ns)_k$	
I	II	I	II	I	II	I	II				
1	2	3	4	5	6	7	8	9	10	11	12
1											
2											
3											
4											
5											
etc.											

Fig. 10.

as their itineraries. This problem is far more extensive than that which, up to now, used to be solved empirically.

It may be assumed that :

1. the transit traffic of the region is not modified;

2. the volume of empty wagons received and forwarded by the inter-regional exchange stations remains the same;

3. on the individual sections of the region studied, the empty wagon kilometrages required for covering the loading requirements of the wayside yards are those which have been determined as described above (this condition is dictated by the lack of precise data on the empty stock requirements of each of the wayside yards for each day of the survey period).

It follows that our research can only relate to the flows of surplus wagons (i.e. wagons surplus to the loading requirements of the wayside yards) already referred to above. In compiling our programme, we can therefore confine ourselves to the empty wagon movements of the junction railheads (which are the terminal stations of the individual sections) provided, however, that in their wagon potentials, the loading requirements of all the wayside yards of the adjoining sections are taken into account.

In order to calculate the wagon potentials of the junction railheads and inter-

Working Sheet N 3		Wagon potentials of the junction railheads and inter-regional wagon exchange yards of the region surveyed							
Names of railheads		Type of wagon :				Survey period :			
		Requirements of the junction and exchange railheads		Numbers of empty wagons received (+) or despatched ( ) by the junction or inter-regional wagon exchange railheads in consequence of the requirements of the adjacent sections of line					Wagon potentials (numbers of wagons)
		Loading	Unloading	1	2	3	4	5	
1									
2									
3									
4									
5									
etc.									

Fig. 11.

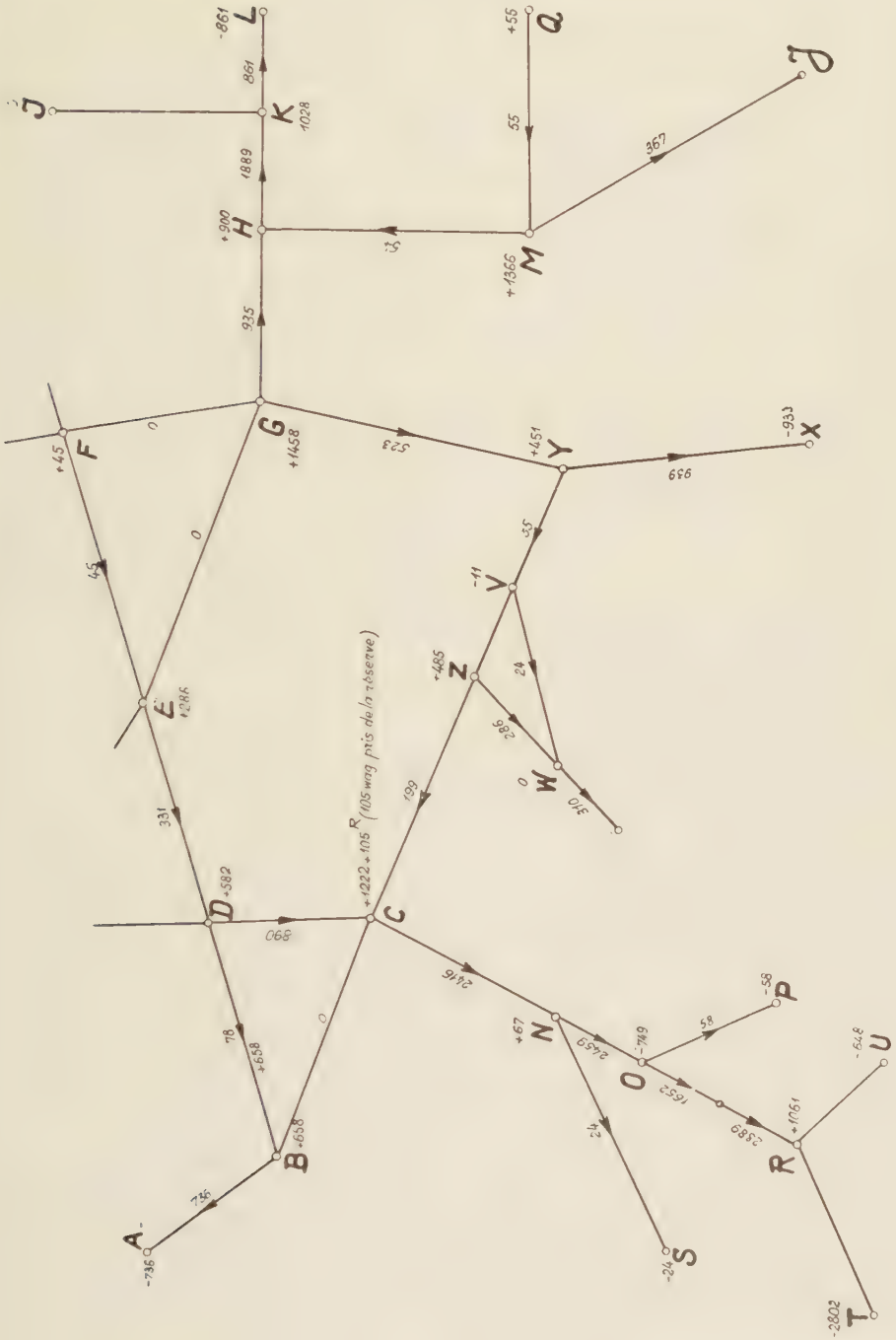


Fig. 12.

N.B. — 105 wag. pris de la réserve = 105 wagons taken from reserve pool.

regional wagon exchange stations, it is useful to have recourse to form N 3 (fig. 11).

Form N 3 shows the wagon potentials of all the junction railheads of the region concerned. These figures are then transferred to the diagrammatic map of that railway region, and the empty wagon kilometrages are determined as described in Section 1.6.

With the aid of the thus completed diagrammatic map of the region (fig. 12), it is possible :

— to calculate the empty wagon kilometrages $\Sigma(ns)_{tp}$ envisaged and
— to determine the best solution for the movement plan of empty wagons.

2.3. Conclusions.

On the strength of the principles outlined in Sections 2.2.1. to 2.2.5., it is possible to draw conclusions concerning :

— those empty wagon kilometrages which are most likely to be wasteful $\Sigma(ns)_{ipp}$,
— those empty wagon kilometrages which are probably wasteful, $\Sigma(ns)_{ip}$,
— the formation of trains of empty wagons running within the region.

The volume of those kilometrages which are most likely to be wasteful, $\Sigma(ns)_{ipp}$, can be calculated from the equation :

$$\Sigma(ns)_{ipp} = \Sigma(ns)_t - \Sigma(ns)_{tp} + 2\cdot\Sigma(ns)_K \quad \text{. . . (wag.-km)}$$

whilst the volume of the probably wasteful kilometrages, $\Sigma(ns)_{ip}$, can be worked out from the equation :

$$\Sigma(ns)_{ip} = 2 \cdot \Sigma(ns)_n \qquad \text{(wag.-km).}$$

In order to assess the possibility of forming trains of empty wagons, the following method might be adopted : the data extracted from columns (7) and (8) of form N 2 are, for each type of wagons, entered on the diagrammatic map of the region in a given order. One thus obtains a single map of the region for all the types of wagons (fig. 13). This map contains numerical data concerning the volume of flows of empty wagons for each individual section.

With the aid of the diagrammatic maps of the region (fig. 12), drawn up and entered in accordance with the principles outlined in Section 2.2.5., for each type of wagon, one prepares a new map similar to the one described above (fig. 13) but relating to an improved solution. By comparing these two maps, it is possible to appraise the possibilities of improving the flow plan of empty wagons and reducing the loss in wagon hours resulting from a less perfect solution.

3. SYNTHETIC METHOD OF ASSESSING THE EFFICIENCY OF EMPTY WAGON CIRCULATION.

Section 2 shows that the analytical method of assessing the circulation of empty wagons, calling for a good deal of research, cannot replace the « synthetic » method which is, in any case, indispensable inasmuch as it permits an appreciation of the overall efficiency of the circulation of empty wagons on the basis of practical data. This synthetic method is based on the following considerations :

The problem of empty wagon circulation has a dual aspect : the empty wagons used for local traffic, incoming traffic and outgoing traffic of the region concerned take part, within the region, in the loading operations. This participation can be

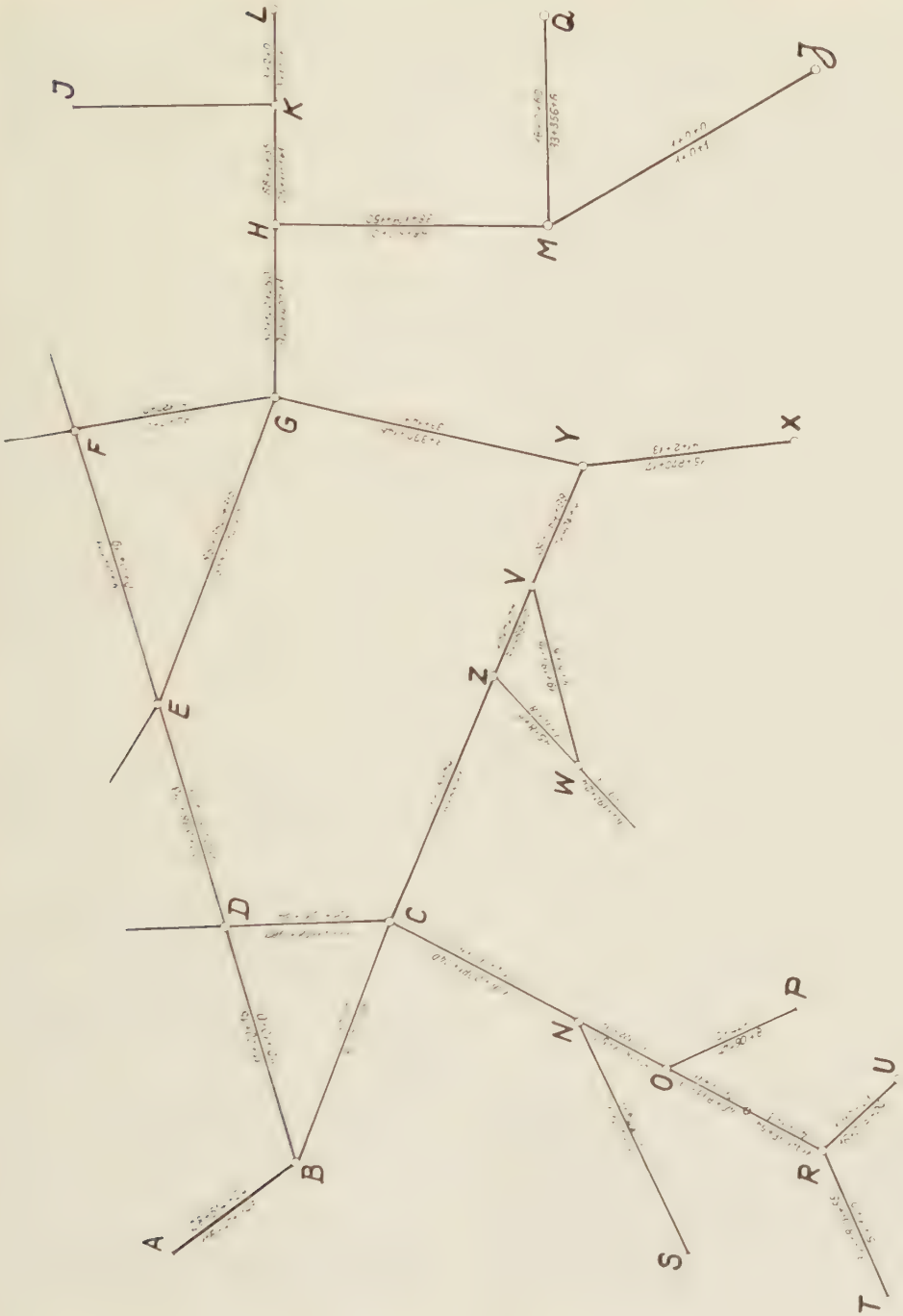


Fig. 13.

expressed by the sum of the loading and unloading operations performed in a given period of time at all the yards of the region examined. In contrast, the empty wagons in transit through the region concerned do not take part in the loading operations performed in that region. Without doubt, the efficiency of the empty wagon circulation within the region must be expressed by the mathematical relation between the number of empty wagons employed in the region, and the number of operations performed by these wagons in the region.

In keeping with this dual function of empty wagons just referred to, it is not sufficient to find a single mathematical formula; it is necessary to find two formulas suitable for solving the problem.

If, in keeping with the conventional notion of the turn-round of empty wagons which comprises, in its cycle, the double loading operations (loading and unloading), we adopt as a criterion for the work performed in the region half the sum of the number of wagons loaded, U_{ch}, and the number of wagons unloaded, U_d, (in the course of 24 hours) i.e.

$$\frac{U_{ch} + U_d}{2},$$

then the formula

$$W_{ov} = \frac{2\,N_{ov}}{U_{ch} + U_d} \text{ (days)},$$

where N_{ov} is the volume of local, incoming and outgoing traffics, will express the efficiency of the circulation of empty wagons in local traffic, incoming traffic and outgoing traffic in the region concerned.

The efficiency of the circulation of empty wagons in transit traffic, W_{tv}, is then expressed by the ratio of the number of these wagons N_{tv} in the region concerned, and half the sum of the number of empty wagons in transit traffic entering and leaving the region concerned within 24 hours (U'_t and U''_t, respectively).

Hence :

$$W_{tv} = \frac{2 \cdot N_{tv}}{U'_t + U''_t} \text{ (days)}.$$

On the assumption that the values W_{ov} and W_{tv} do, in fact, provide a practical criterion for the circulation of empty wagons, it is necessary to devise a practical method of recording the independent variables U_{ch}, U_d, U'_t, U''_t, N_{ov} and N_{tv}.

3.1. Method of recording and calculating the numbers of empty wagons, N_{ov} and N_{tv}, and the values U'_t and U''_t.

I. *Recording of data.*

As a practical way of ascertaining the variables N_{ov}, N_{tv}, U'_t and U''_t, it is convenient to adopt the principles outlined below and to proceed in the following manner :

1. It is desirable to provide the empty wagons with labels which indicate the forwarding yard and the station of destination of the empty wagon as well as a code index of the region to which the wagon belongs, and a code indicating the type of wagon.

2. The data furnished by the wagon labels should be recorded in the train sheet.

3. For each train crossing the border of a region, it is necessary to fill in form A (fig. 14), recording the particulars obtained

Form A	Inter-regional wagon exchange yard :	Region :
Train No. :		Date :

1	2	3
Type of wagon :	Number of empty wagons having crossed the regional border :	Number, included in col. 2, of empty wagons despatched by the railheads of the region surveyed
Covered wagons :		
High-sided open wagons :		
Flat wagons :		
Special wagons :		
Total :		

Fig. 14.

from the train sheet. The data entered in this form will ultimately serve for the accounting of empty wagons exchanged at the inter-regional exchange yards.

4. The accounting work to be performed at the wagon exchange yards consists, first of all, in adding up the above mentioned data from all the forms A for a freely chosen period of time (24, 12, 6 or 4 hours), separately for each direction of running, and then to prepare, on the basis of these data, a summary sheet similar to form A. The data entered on this form are forwarded to the headquarters offices of the two regions concerned.

5. Regional headquarters will add up the data extracted from the forms forwarded by all its wagon exchange yards and will fill in, separately for incoming and outgoing trains, a new sheet similar to form A. In this way, the headquarters office will obtain particulars concerning the numbers of empty wagons (classified by types of wagons) which have entered the region, or left the region, within a given period of time.

6. In addition, all the railheads are required to fill in forms of type B (fig. 15) and type C (fig. 16) for the same period of time. All the wagon labels mentioned under (1) above must be removed from the empty wagons when these are loaded at these stations, and will yield the particulars which are entered in a form of type D (fig. 17).

Form B	Railhead : ..... Region :	Date :
Type of wagon :	Numbers of wagons unloaded :	
Covered wagons :		
High-sided open wagons :		
Flat wagons :		
Special wagons :		
Total :		

Fig. 15.

Form C	Railhead :	Region :	Date :
Type of wagon :	Numbers of wagons unloaded :		
Covered wagons :			
High-sided open wagons :			
Flat wagons :			
Special wagons :			
Total :			

Fig. 16.

7. The data obtained from the three forms (B, C and D) are forwarded by the yards to regional headquarters.

II. *Calculation of the number of empty wagons.*

This calculation can be carried out by regional headquarters on the basis of the records discussed in Section I, based on a period of 24, 12, 6 or 4 hours, and classified by types of wagons.

A distinction should be made between the following traffics :

transit traffic : both the forwarding yard and the station of destination of the empty wagon are situated outside the borders of the region;

Form D	Railhead :	Region :	Date :
1	2	3	
Type of wagon :	Number of empty wagons loaded, excluding those wagons previously unloaded at the same yard (« double loading operation »)	Number, included in col. 2, of empty wagons loaded, having been received from yards within the region surveyed :	
Covered wagons :			
High-sided open wagons :			
Flat wagons :			
Special wagons :			
Total :			

Fig. 17.

— incoming traffic : the forwarding yard of the empty wagon is situated outside the borders of the region concerned, whilst the station of destination is inside the region;

— outgoing traffic : the forwarding yard of the empty wagon is situated within the region concerned, whilst the station of destination is situated outside its borders;

— local traffic : both the forwarding yard and the station of destination are situated within the region concerned.

The need for thus dividing the total number of empty wagons into the numbers belonging to each of these categories of traffic arises from the fact that, in keeping with the definition of these traffics, the forwarding yards and stations of destination, i.e. the points at which these flows of empty wagons originate and end, are either within or outside the region concerned so that the numbers of these empty wagons depend partly on the region itself, partly on another region.

The number of empty wagons within the region can be calculated as follows :

1. The total number of empty wagons can be worked out from the formula

$$N_v = N^o{}_v + U'_v - U''_v + U_d - U_{ch} \quad \ldots \quad \text{(wag.)}$$

where :

$N^o{}_v$ is the similar number applying to the end of the preceding period of time;

U'_v is the number of all the empty wagons which have entered the region concerned during the reference period of

time; this number is obtained from a form of type A (cf. item 5 of Section 3.1.);

U''_v is the number of all the empty wagons which have left the region concerned during the reference period of time; this number is obtained from a form of type A;

U_d is the number of wagons unloaded during the reference period of time; this number is obtained from a form of type C;

U_{ch} is the number of empty wagons loaded during the reference period of time; this number is taken from the form of type B.

2. The number of empty wagons in transit traffic, N_{tv}, is calculated with the aid of the formula :

$$N_{tv} = N^o_{tv} + U'_v - U_x - U''_v + U_y \quad \text{(wag.)}$$

where :

N^o_{tv} is the similar number applying to the end of the preceding period of time;

U_x is the number of empty wagons received from other regions and loaded during the reference period of time; this number is ascertained from the form of type D (difference between columns 1 and 2);

U_y is the number of empty wagons forwarded by the railheads belonging to the region concerned; this number is obtained from column 3 of the form of type A.

The significance of U'_v and U''_v has already been explained above.

3. The total numbers of wagons in local traffic, incoming traffic and outgoing traffic can be calculated with the aid of the formula :

$$N_{ov} = N^o_v - N^o_{tv} + U_d - U_{ch} + U_x - U_y \quad \text{. . . . (wag.)}$$

The significance of, and method of determining, the different variables have already been explained.

Finally, U'_t and U''_t are calculated from the following formulae :

$$U'_t = U'_v - U_x \quad \text{(wag.)}$$
$$U''_t = U''_v - U_y \quad \text{(wag.)}$$

The significance and method of determining the variables contained in these formulas have likewise been explained already.

4. The calculations set out above may be carried out either separately for each type of wagon, or jointly for all the wagons together.

3.2. Simplified utilisation of the general formula $W_{ov} = \frac{2 \cdot N_{ov}}{U_{ch} + U_d}$ concerning the turn-round of empty wagons.

If it is not desired to calculate the total number N_{ov} of empty wagons in local traffic, incoming traffic and outgoing traffic, and if it is sufficient to record the total number of empty wagons N_v (including the wagons in transit traffic), use may be made of the general formula concerning the turn-round of empty wagons, after transforming it as follows :

We know that $N_v = N_{ov} + N_{tv}$

where N_{tv} is the number of empty wagons in transit through the region concerned; hence :

$$W_{ov} = \frac{2 \cdot N_{ov}}{U_{ch} + U_d} = \frac{2 \cdot (N_v - N_{tv})}{U_{ch} + U_d} \quad (5)$$

By substituting $C_v = \frac{W_{tv}}{W_{ov}}$, where W_{tv} is the time required by the empty wagons in transit traffic to cross the region, one thus obtains :

$$N_{tv} = W_{tv} \cdot U_t ,$$

where : $$U_t = \frac{U'_t + U''_t}{2} .$$

The significance of U'_t and U''_t has already been explained at the beginning of Section 3.

From : $N_{tv} = C_v \cdot W_{ov} \cdot U_t$

and formula (5), we now obtain :

$$W_{ov} = \frac{2 \cdot (N_v - C_v \cdot W_{ov} \cdot U_t)}{U_{ch} + U_d}$$

$$= \frac{2 \cdot N_v}{U_{ch} + U_d + 2 \cdot C_v \cdot U_t} \text{ (days)} \quad (6)$$

It is fairly easy to ascertain and calculate all the independent variables in formula (6), viz. N_v, U_{ch}, U_d and U_t (see Part II of Section 3.1.), whilst the parameter C_v, which is the quotient of the average time W_{tv} required by an empty wagon in transit traffic to cross the region, and the time W_{ov} representing the turn-round period of empty wagons in that region, may in these calculations either be regarded as a constant, or as an empiric value.

If C_v is regarded as a constant, we have to determine the difference between the calculated and actual values of the wagon turn-round.

Our reasoning will then be as follows :

If K denotes the absolute variation of C_v, and z the relative variation of $C_v \left(z = \frac{k}{C_v} \right)$, the relative variation S of the wagon turn-round W_{ov} can be calculated as follows :

$$S = \frac{W_{ov}(C_v + K) - W_{ov}(C_v)}{W_{ov}(C_v)}$$

$$= \frac{W_{ov}(C_v + K)}{W_{ov}(C_v)} - 1 .$$

By substituting, in this formula, the value W_{ov} determined by formula (6), one obtains :

$$S = \frac{2 \cdot N_v [U_{ch} + U_d + 2 \cdot C_v \cdot U_t]}{[U_{ch} + U_d + 2 \cdot U_t (C_v + K)] \cdot 2N_v} - 1$$

$$- \frac{U_{ch} + U_d + 2 \cdot C_v \cdot U_t}{U_{ch} + U_d + 2 \cdot C_v \cdot U_t + 2 \cdot U_t \cdot K} - 1$$

$$= \frac{1 + 2 \cdot C_v \frac{U_t}{U_{ch} + U_d}}{1 + 2 \cdot C_v \frac{U_t}{U_{ch} + U_d} + 2 \cdot C_v \frac{U_t}{U_{ch} + U_d} \cdot \frac{K}{C_v}} - 1 \quad (7)$$

By substituting $x = \frac{U_t}{U_{ch} + U_d}$ and $z = \frac{K}{C_v}$, formula (7) is finally transformed into

$$S = \frac{1 + 2 \cdot C_v \cdot x}{1 + 2 \cdot C_v \cdot x + 2 \cdot C_v \cdot x \cdot z} - 1 \quad (8)$$

Equation (8) represents a family of hyperbolas $s = f(z)$ containing the parameters C_v and x, the values of which are liable to vary within certain limits.

The diagram, figure 18, is plotted in the z and S plane, and its variables are expressed in per cent.

It will be seen from figure 18 that a high value of z yields a low value of S, and that the degree to which the variations in the magnitude of S are influenced by the variations in the magnitude of z is dependent on the values of the parameters C_v and x, which are constant for each curve.

The reciprocal combinations of the values of C_v and x relevant to our study are tabulated in the table included in figure 18, and it is for these values that the curves in figure 18 have been plotted.

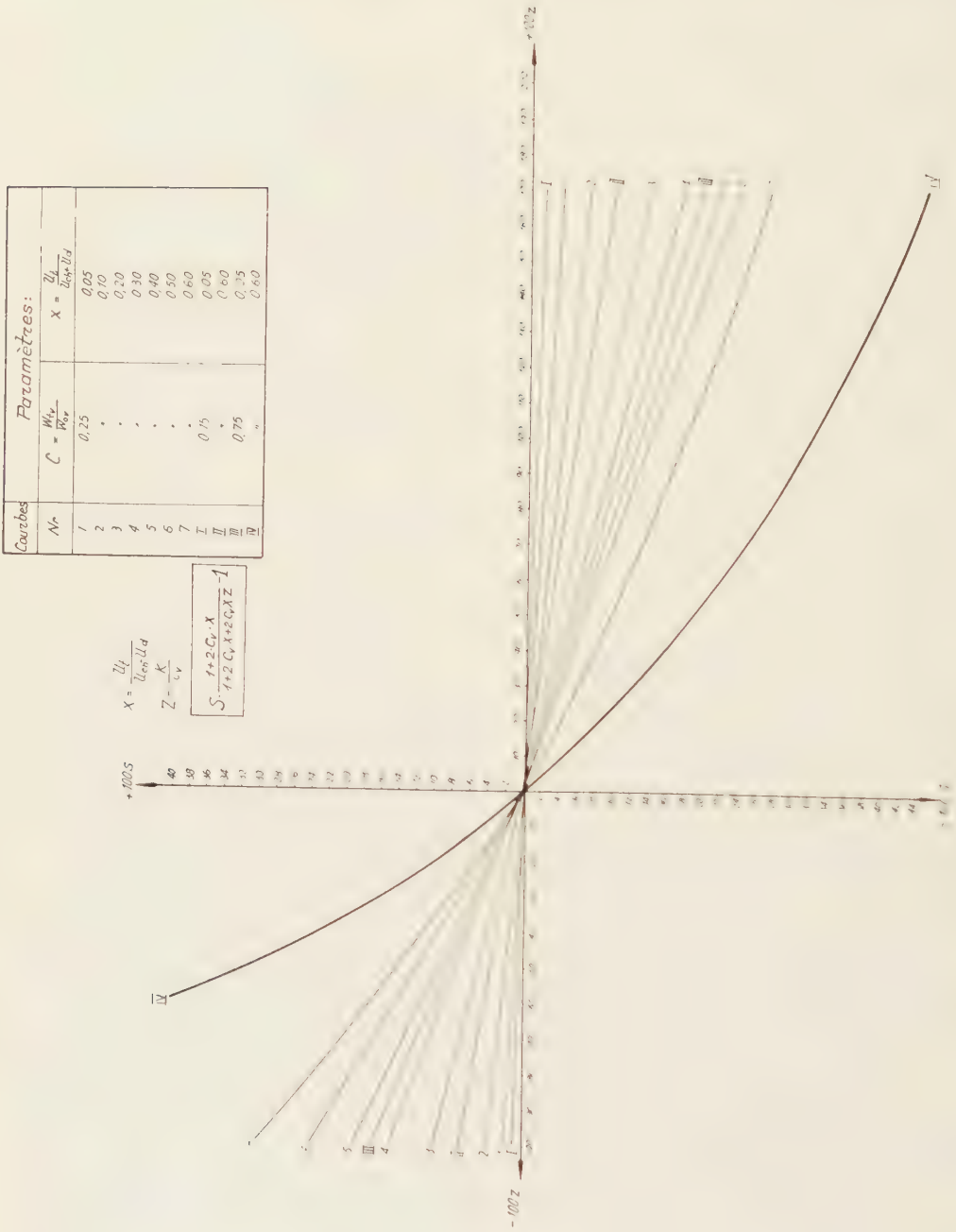


Fig. 18.

N.B. — Courbes = curves. — Paramètres = parameters.

Curve (3), plotted for the mean values of C_v and x, shows that, for $z = 50$, i.e. if the chosen value of C_v differs from the real value by 50 %, the variation of S amounts to 3.5. In other words, the difference between the calculated and real values of the turn-round of empty wagons does not exceed 3.5 %.

It will thus be seen that it is possible to obtain sufficiently accurate values of W_{ov} by calculating them with the aid of formula (6), which represents a transformation of the principal formula

$$W_{ov} = \frac{2 \cdot N_{ov}}{U_{ch} + U_d},$$

if the value of the parameter C_v, used in formula (6), is known approximately. The difference between the value attributed to C_v and its real value has little effect on the accuracy of the calculation affected with the aid of formula (6), as is proved by the shape of the hyperbolas of figure 18.

In order to determine the magnitude of the parameter $C_v = \frac{W_{tv}}{W_{ov}}$, it is sufficient, once a year, to investigate by the direct method the time required by the empty transit wagons, W_{tv}, to cross the region concerned. For this purpose, we first calculate the average transit times for each transit route, and then take into consideration the volume of the flows of empty wagons on each of these different transit routes so that the overall mean transit time W_{tv} can be calculated.

As regards the length of the turn-round time of empty wagons, W_{ov}, this can be calculated from formula (6), applied to the preceding reference period.

In order to determine the value U_t which appears in formula (6), the method outlined in Section 3.1. should be followed.

4. APPLICATION, BY WAY OF EXAMPLE, OF THE DESCRIBED METHOD TO A REGION OF THE POLISH STATE RAILWAYS (*)

4.1. General data.

The author has examined the movements in this region for the period from 11th March to 10th April, 1958. This period has been divided into three ten-day periods. Whilst the first two of the latter did not include any additional holidays, the April period included Easter, which may have had an influence on the circulation of empty stock.

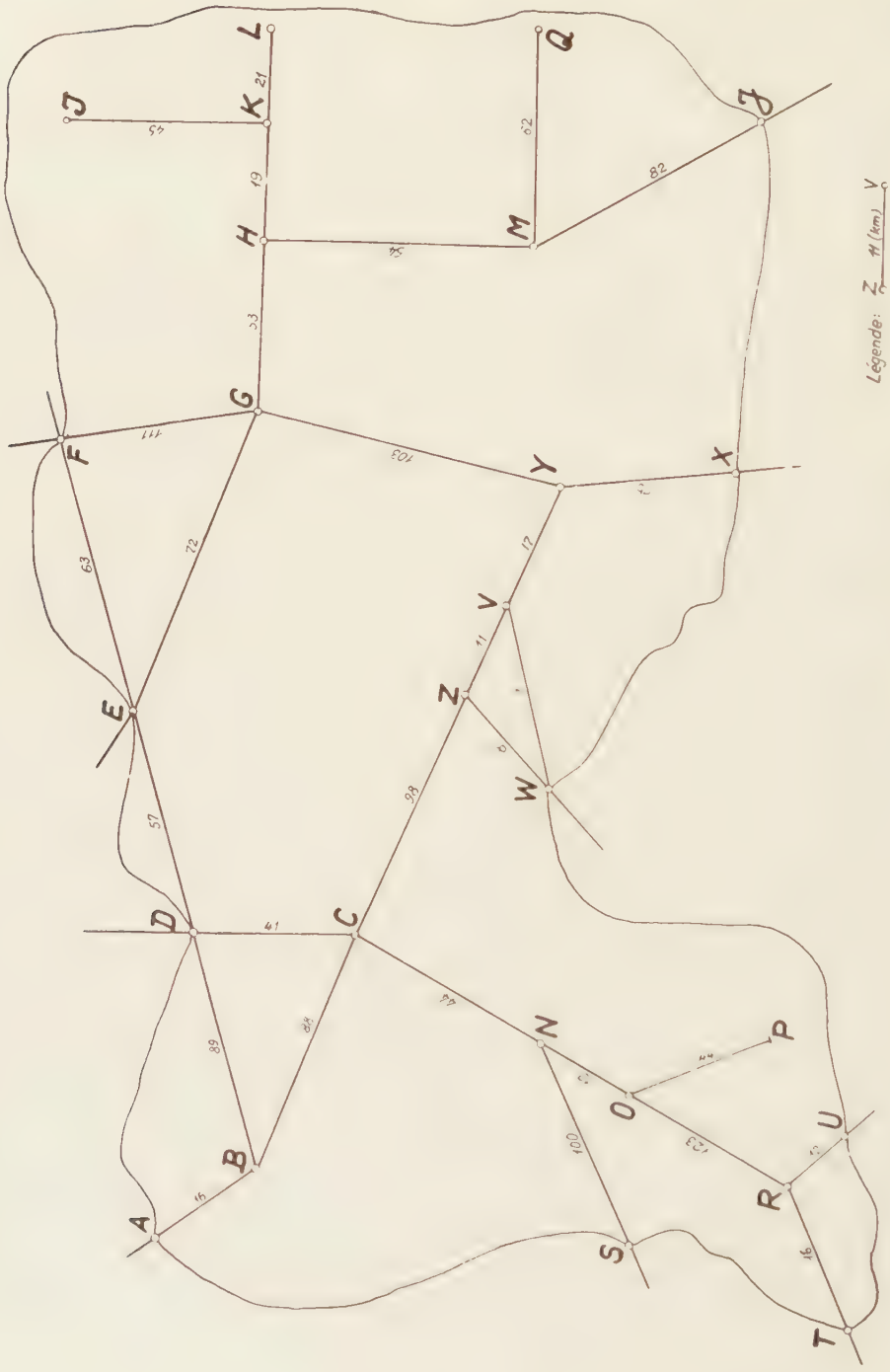
On 20th February, 1958, the author wrote to the Operating Manager of the Polish State Railways, indicating the method to be followed in assembling the necessary data in keeping with the method proposed by him and described in Section 2.1., and asking for the co-operation of the staff of the Operating Department.

The data thus collected were forwarded by the yards concerned to the research centre, directed by the author, where 12 basic data sheets (**) were compiled of the type shown in figure 6, section 2.1., viz. one for each of the three ten-day periods and each of the four types of wagons (covered wagons, high-sided open wagons, flat wagons, and special wagons).

It had been the intention to complete these data sheets by about mid-May, 1958, but errors were detected in the collection

(*) The diagrammatic map of this region, showing the location of the junction railheads and wagon exchange yards, is reproduced in fig. 19.

(**) The compilation of these 12 basic data sheets called for nearly 1 500 working hours.


L
Q
J
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21
54
62
Z
82
19
H
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35
53
G
111
105
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X
63
72
17
V
11
E
Z
57
98
W
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41
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N
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B
15
S
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16
Légende: Z M (km) V

Fig. 19.

TABLE 3.

Types of wagons : / Period :	Covered wagons	High-sided open wagons	Flat wagons	Special wagons	Totals
2nd ten-day period, March 1958	5 927	14 686	5 681	2 133	28 427
3rd ten-day period, March 1958	5 719	16 500	5 252	2 155	29 626
1st ten-day period, April 1958	3 984	13 106	3 548	1 658	22 296
Totals . . .	15 630	44 292	14 481	5 946	80 349

of the data so that it was deemed necessary to obtain supplementary data. The data sheets were therefore not ready before September, 1958.

On the basis of these tables, 36 flow diagrams of empty wagons were drawn up (*) of the type shown in figure 7, section 2.2., viz. one diagram for each ten-day period, for each of the four types of wagons, and for each of the following traffic categories : (i) transit traffic; (ii) incoming and outgoing traffic; (iii) local traffic, i.e. $3 \times 4 \times 3 = 36$ diagrams.

The final processing (carried out as described in Section 2) called for another 800 working hours. Altogether, the Research Office thus spent 3 300 working hours on the complete study, representing a monetary value of approx. 30 000 zlotys.

4.2. **Detailed study of the region.**

The numbers of empty wagons covered by the circulation study are given in table 3.

The numbers of unloading and loading operations of these wagons as well as the numbers of empty wagons entering and leaving the region through the wagon exchange stations are summarized in table 4 (**) (with the exception of the special wagons which are not of interest in connection with our survey).

The sometimes positive, sometimes negative discrepancies in this table may be due to the variations in the number of empty wagons in the region during the ten-day periods considered.

4.2.1. *Transformation of the data contained in the basic data sheets* (of the type show in fig. 6) *and of the flow diagrams of empty wagons* (of the type shown in fig. 7).

In accordance with the method outlined in Sections 2.2.4. and 2.2.5., forms N 1, N 2, and N 3 were prepared in the manner illustrated by figures 9, 10 and 11, using the basic data sheets (fig. 6) and the flow diagrams of empty wagons (fig. 7). This was done separately for each of the three ten-day periods and for each type of wagons (covered wagons, high-sided open wagons, flat wagons).

(*) These 36 flows diagrams of empty wagons accounted for nearly 1 000 working hours.

(**) Data extracted from the basic data sheets.

TABLE 4.

Period : / Types of wagons :		Covered wagons	High-sided open wagons	Flat wagons
2nd ten-day period, March 1958	Unloading	5 735	12 387	4 256
	Loading	8 160	8 041	5 138
	Diff. between unloading and loading	— 2 425	+ 4 346	— 882
	Incoming	2 709	1 377	1 708
	Outgoing	371	5 761	948
	Diff. between incoming and outgoing	+ 2 338	— 4 384	+ 760
	Discrepancy	— 87	— 38	— 122
3rd ten-day period, March 1958	Unloading	6 401	14 277	4 833
	Loading	8 577	8 017	4 600
	Diff. between unloading and loading	— 2 176	+ 6 260	+ 233
	Incoming	2 406	1 500	1 022
	Outgoing	448	7 709	1 203
	Diff. between incoming and outgoing	+ 1 958	— 6 209	— 181
	Discrepancy	— 218	— 51	— 52
1st ten-day period, April 1958	Unloading	5 304	11 197	3 293
	Loading	6 068	6 594	3 986
	Diff. between unloading and loading	— 764	+ 4 603	— 693
	Incoming	1 101	1 346	1 058
	Outgoing	410	5 984	400
	Diff. between incoming and outgoing	+ 691	— 4 638	658
	Discrepancy	— 73	— 35	— 35

An improved circulation scheme for empty wagons was then drawn up by plotting it on the flow diagrams of the region concerned (Section 2.2.5.). This was followed by preparing, separately for each ten-day period :

— the diagrammatic maps of the actual trips of empty wagons (cf. fig. 13, Section 2.3.);

— the diagrammatic maps of the improved trips of empty wagons.

Neither the transit traffic nor the traffic of special wagons were included in this study.

4.2.2. *Analysis of the empty wagon kilometrages*

With the aid of the flow diagrams of empty wagons (fig. 7), the counter-running kilometrages were calculated separately for local traffic, incoming traffic and outgoing traffic. The results were tabulated for each section and summarized in a table for the region as a whole; this table is shown below (table 5).

As already mentioned (Sections 2.2.3. and 2.2.4.), the unproductive kilometrages $\Sigma(ns)_s$ are composed of unproductive but probably unavoidable kilometrages $\Sigma(ns)_n$, and unproductive but, at the same time, probably avoidable kilometrages $\Sigma(ns)_k$, i.e. :

$$\Sigma(ns)_s = \Sigma(ns)_n + \Sigma(ns)_k.$$

With the aid of forms N 2 (fig. 10), the data pertaining to the kilometrages $\Sigma(ns)_k$

TABLE 5.

Unproductive wagon kilometrages $\Sigma(ns)_s$ caused by counter-running of empty wagons.

Types of wagons : / Period :	Covered wagons	High-sided open wagons	Flat wagons	Totals
2nd ten-day period, March 1958	146 606	177 578	155 032	479 216
3rd ten-day period, March 1958	173 952	219 200	114 315	507 467
1st ten-day period, April 1958	106 601	168 074	55 310	329 985
Totals . . .	427 159	564 852	324 657	1 316 668

TABLE 6.

Unproductive and, at the same time, probably wasteful wagon kilometrages $\Sigma(ns)_k$ of empty wagons.

Types of wagons : / Period :	Covered wagons	High-sided open wagons	Flat wagons	Totals
2nd ten-day period, March 1958	62 720	83 820	74 960	221 500
3rd ten-day period, March 1958	96 102	132 660	63 620	292 382
1st ten-day period, April 1958	63 016	83 458	25 098	171 572
Totals . . .	221 838	299 938	163 678	685 454

were calculated, and the results were tabulated in table 6.

From tables 5 and 6, it is obviously possible to calculate the wagon kilometrages $\Sigma(ns)_n$.

Table 7 shows the total wagon kilometrages $\Sigma(ns)_o$ incurred within the region concerned by empty wagons forming part of incoming traffic, outgoing traffic and local traffic, for the three different ten-day periods, and for each type of wagon.

The values $\Sigma(ns)_o$ are calculated from the formula :

$$\Sigma(ns)_o = \Sigma(ns)_p + \Sigma(ns)_t$$

where $\Sigma(ns)_p$ and $\Sigma(ns)_t$ are obtained from forms N 1 (fig. 9) and N 2 (fig. 10), respectively.

With the aid of the diagrammatic maps of the region showing the improved runs (maps of the type shown in fig. 12), the total empty wagon kilometrages $\Sigma(ns)_{tp}$ between the junction railheads of the region concerned were worked out and entered in table 8.

The savings in empty wagon kilometrage between the junction railheads amount to :

$$\Delta\Sigma(ns) = \Sigma(ns)_t - \Sigma(ns)_{tp}$$

TABLE 7.

Total wagon kilometrage $\Sigma(ns)_o$ of empty wagons forming part of incoming, outgoing and local traffic.

Types of wagons : / Period :	Covered wagons	High-sided open wagons	Flat wagons	Totals
2nd ten-day period, March 1958	459 610	1 072 640	444 930	1 977 180
3rd ten-day period, March 1958	427 954	1 277 491	359 847	2 065 293
1st ten-day period, April 1958	258 662	972 563	312 956	1 544 181
Totals . . .	1 146 226	3 322 694	1 117 733	5 586 653

TABLE 8.

Wagon kilometrages $\Sigma(ns)_{tp}$ of empty wagons between junction stations.

Types of wagons : / Period :	Covered wagons	High-sided open wagons	Flat wagons	Totals
2nd ten-day period, March 1958	273 314	643 480	235 590	1 152 384
3rd ten-day period, March 1958	242 166	751 379	178 371	1 171 916
1st ten-day period, April 1958	121 041	527 960	215 784	864 785
Totals . . .	636 521	1 922 819	629 745	3 189 085

where $\Sigma(ns)_t$ is obtained from forms N 2 whilst $\Sigma(ns)_{tp}$ is extracted from table 8.

The result of the calculation is entered in table 9.

As has been shown in Sections 1 and 2, it is quite impossible to establish, after the event, the absolute unproductivity of certain movements of empty wagons without resorting either to the probability method, which calls for prolonged research at all the yards of the regions, or to the elementary analysis of the movement of almost every empty wagon.

It is, however, possible to determine the unproductive movements $\Sigma(ns)_o$ by dividing them into two groups : the first, $\Sigma(ns)_k$, comprising the runs which are most likely to be unproductive; the second, $\Sigma(ns)_n$, containing those runs which, though unproductive, are probably unavoidable.

Moreover, it is also possible to define,

TABLE 9.

Savings in wagon kilometrage, $\Delta\Sigma(ns)$, effected in runs of empty wagons between junction railheads.

Types of wagons : / Period :	Covered wagons	High-sided open wagons	Flat wagons	Totals
2nd ten-day period, March 1958	81 006	132 100	108 950	322 056
3rd ten-day period, March 1958	96 402	187 621	82 309	366 332
1st ten-day period, April 1958	68 602	137 802	28 306	234 710
Totals . . .	246 010	457 523	219 565	923 098

as the runs most likely to be unproductive, the kilometrages $\Delta\Sigma(ns)$, representing the difference between the runs actually carried out between the junction railheads, and the runs which would have had to be worked under the rationalized plan.

By drawing judicious conclusions from these data, one might expect to obtain a maximum saving, for the region concerned, and for the three successive ten-day periods considered, amounting either to :

$$\frac{1\,316\,668 \cdot 100\ (*)}{5\,586\,653\ (**)} = 23.4\ \%.$$

or, by rationalizing the runs between junction railheads (table 9) and excluding the unproductive runs $\Sigma(ns)_n$ (difference of the data obtained from tables 5 and 6, respectively) to :

$$\frac{1\,554\,312 \times 100}{5\,586\,653} = 28\ \%.$$

where : 1 554 312 = 923 098 + (1 316 668 — 685 454) wagons/kilometres.

(*) Data obtained from table 5.
(**) Data obtained from table 7.

4.2.3. *Analysis of the movement plan for emply wagons.*

As already mentioned, the data extracted, for each section, from columns 7 and 8 of forms N 2 (fig. 10) are entered in the following order : covered wagons, high-sided open wagons, flat wagons, against the appropriate sections of the diagrammatic maps of the region, separately for each ten-day period. We thus obtain maps similar to the model, figure 13. The numbers are entered against each section above or below the line, according to the direction of running, assuming right-hand running.

When these data have been entered on the maps, one endeavours to organize these flows of empty wagons in trains with the longest possible runs.

The results of this study are tabulated in table 10 which shows the numbers of empty wagons in incoming, outgoing and local traffic, available to form direct trains of empty wagons.

If the minimum compositions shown in table 10 are taken as a basis, it is found

TABLE 10.

Traffic relation No.	Itinerary of traffic relation (cf. fig. 19)	Period	Train composition			
			Number of empty wagons			
			covered	high-sided open	flat	total
1	2	3	4			
1	D-C-N-O-R-T	2nd ten-day period, March . . .	45	+ 1 014	+ 143	= 1 200
		3rd ten-day period, March . . .	45	+ 846	+ 50	= 981
		1st ten-day period, April	34	+ 893	+ 13	= 940
		Minimum composition	34	+ 846	+ 13	= 893
2	E-D-C-N-O	2nd ten-day period, March . . .	17	+ 475	+ 496	= 988
		3rd ten-day period, March . . .	49	+ 0	+ 292	= 341
		1st ten-day period, April	33	+ 215	+ 559	= 807
		Minimum composition	33	+ 0	+ 292	= 325
3	A-B-C-N	2nd ten-day period, March . . .	237	+ 85	+ 268	= 590
		3rd ten-day period, March . . .	99	+ 51	+ 0	= 150
		1st ten-day period April	39	+ 47	+ 168	= 252
		Minimum composition	39	+ 47	+ 0	= 86
4	D-E-G-H	2nd ten-day period, March . . .	430	+ 4	+ 2	= 436
		3rd ten-day period, March . . .	410	+ 49	+ 4	= 463
		1st ten-day period, April	159	+ 52	+ 0	= 211
		Minimum composition	159	+ 59	+ 0	= 208
5	E-G-H	2nd ten-day period, March . . .	436	+ 126	+ 0	= 562
		3rd ten-day period, March . . .	512	+ 90	+ 2	= 604
		1st ten-day period, April	199	+ 22	+ 0	= 221
		Minimum composition	199	+ 22	+ 0	= 221

TABLE 10 *(continued)*.

Traffic relation No.	Itinerary of traffic relation (cf. fig. 19)	Period	Train composition — Number of empty wagons			
			covered	high-sided open	flat	total
1	2	3	4			
6	F-G-H	2nd ten-day period, March. . .	150 +	57 +	59 =	266
		3rd ten-day period, March . . .	170 +	14 +	73 =	257
		1st ten-day period, April	84 +	7 +	0 =	91
		Minimum composition	84 +	7 +	0 =	91
7	G-Y-V-W	2nd ten-day period, March . . .	0 +	205 +	231 =	436
		3rd ten-day period, March . . .	62 +	293 +	430 =	785
		1st ten-day period, April	3 +	184 +	16 =	203
		Minimum composition	0 +	184 +	16 =	200
8	Z-V-Y-X	2nd ten-day period, March . . .	24 +	567 +	12 =	603
		3rd ten-day period, March . . .	18 +	470 +	13 =	501
		1st ten-day period, April	3 +	369 +	4 =	376
		Minimum composition	3 +	369 +	4 =	376

possible to work, for the incoming, outgoing and local traffic of the region concerned, 120-axle trains of empty wagons in the following relations :

— relation N 1 : one train per day and, in addition, three times per week, a train composed of high-sided open wagons;

— relation N 2 : three times per week, a train mainly composed of flat wagons;

— relation N 4 : three times per week, a train composed of covered wagons;

— relation N 5 : twice a week, a train composed of covered wagons;

— relation N 7 : twice a week, a train composed of high-sided open wagons;

— relation N 8 : three times per week, a train composed of high-sided open wagons.

Whilst the regular trains in relation N 1

are certainly advantageous, the empty wagons forming the trains in relations NN 2, 4, 5, 7 and 8 could, with advantage, be attached as special groups to scheduled trains of loaded wagons.

These are the *possibilities* for a movement plan for the most important flows of empty wagons forming part of the incoming, outgoing and local traffic of the region concerned.

These possibilities have been established in accordance with existing conditions and with the conceptions adopted for the movement of empty wagons. As table 10 shows, it is possible to form at least one train per day (relation N 1) crossing the region concerned; in addition, it is possible to form groups of empty wagons of sufficiently great importance which carry out long runs and form part of the incoming traffic (relations NN 2, 3, 4, 5, 6) and of the outgoing traffic (relations NN 7 and 8).

In actual practice, the movements of empty wagons in the region concerned are quite different. As the analysis of the flow diagrams of empty wagons (maps of the type shown in fig. 7) shows, there is a heavy reduction in the volume of the flows of empty wagons, rendering it more difficult to organize these wagons either in special trains of empty wagons or in smaller groups, attached to trains of loaded wagons.

The flows of empty wagons forming part of the transit traffic of the region concerned have not been included here, although, as shown in Table 10, this would be perfectly feasible for relation N 1.

This restriction is certainly detrimental to the results of the survey.

At the time when this survey was carried out, a number of empty wagons were passing in transit through the region concerned. This movement consisted exclusively of wagons which, even at that time, were recognized to be forming part of transit traffic. Also, their number was fairly small so that there seemed to be little point in taking them into consideration in this survey.

If the circulation of empty wagons in the region concerned would be rationalized in the manner described in Section 2.2.5. it would be possible to organize these flows as shown in Table 11.

If the minimum compositions shown in Table 11 are taken as a basis, it would be possible to work 120-axle trains in the following relations :

— relation N 1 : once a day, composed of high-sided open wagons;

— relation N 2 : twice a week, composed of flat wagons;

— relation N 5 : once a day, composed of covered wagons;

— relation N 6 : once a day, composed of high-sided empty wagons;

— relation N 8 : three times a week, composed of high-sided open wagons.

When comparing the movements of empty wagons, the numbers of which are shown in Table 11, carried out with the aid of these trains, with the non-organized movements, it will be found that the savings in terms of wagon hours, which can be effected by through workings of empty wagons through junction railheads, amount to :

TABLE 11.

Traffic relation No.	Itinerary of traffic relation (cf. fig. 19)	Period	Train composition			
			Number of empty wagons			
			covered	high-sided open	flat	total
1	2	3	4			
1	D-C-N-T	2nd ten-day period, March . . .	0 +	1 170 +	147 =	1 317
		3rd ten-day period, March . . .	0 +	890 +	0 =	890
		1st ten-day period, April	0 +	741 +	5 =	746
		Minimum composition	0 +	741 +	0 =	741
2	E-D-C-N-O	2nd ten-day period, March . . .	0 +	92 +	475 =	567
		3rd ten-day period, March . . .	0 +	0 +	251 =	251
		1st ten-day period, April	0 +	0 +	488 =	488
		Minimum composition	0 +	0 +	251 =	251
3	A-B-C-N	2nd ten-day period, March . . .	193 +	0 +	108 =	301
		3rd ten-day period, March . . .	38 +	0 +	89 =	127
		1st ten-day period, April	0 +	0 +	97 =	97
		Minimum composition	0 +	0 +	89 =	89
4	D-E-G-H	2nd ten-day period, March . . .	330 +	0 +	0 =	330
		3rd ten-day period, March . . .	356 +	0 +	0 =	356
		1st ten-day period, April	74 +	0 +	0 =	74
		Minimum composition	74 +	0 +	0 =	74
5	E-G-H (instead of relation 4)	2nd ten-day period, March . . .	761 +	0 +	86 =	847
		3rd ten-day period, March . . .	842 +	0 +	0 =	842
		1st ten-day period, April	400 +	0 +	0 =	400
		Minimum composition	400 +	0 +	0 =	400

TABLE 11 *(continued)*.

Traffic relation No.	Itinerary of traffic relation (cf. fig. 19)	Period	Train composition — Number of empty wagons			
			covered	high-sided open	flat	total
1	2	3	4			
6	G-H-K-L	2nd ten-day period, March . . .	11	694	3	708
		3rd ten-day period, March . . .	3	861	0	864
		1st ten-day period, April	3	322	0	325
		Minimum composition	3	322	0	325
7	G-H-K	2nd ten-day period, March . . .	68	413	65	546
		3rd ten-day period, March . . .	72	74	0	146
		1st ten-day period, April	0	0	0	0
		Minimum composition	0	0	0	0
8	G-Y-X	2nd ten-day period, March . . .	0	391	0	391
		3rd ten-day period, March . . .	0	523	1	524
		1st ten-day period, April	0	433	3	436
		Minimum composition	0	433	0	433
9	G-Y-V-W	2nd ten-day period, March . . .	0	0	185	185
		3rd ten-day period, March . . .	0	0	310	310
		1st ten-day period, April	0	0	0	0
		Minimum composition	0	0	0	0

for the trains in relation N 1 : 2.2953 · t, representing a saving of 5906 · t wag.-hrs.
for the trains in relation N 2 : 3.1306 · t, representing a saving of 3918 · t wag.-hrs.
for the trains in relation N 5 : 2089 · t, representing a saving of 2089 · t wag.-hrs.
for the trains in relation N 6 : 2.1894 · t, representing a saving of 3788 · t wag.-hrs.
for the trains in relation N 8 : 1351 · t, representing a saving of 1351 · t wag.-hrs.

i.e. a total saving of $\Sigma(nh) = 17052 \times t$ wag.-hrs.

where t represents the average time of call of an empty wagon at a junction railhead.

If this time is assumed to be $t = 10$ hours, one obtains a total saving, during the three ten-day periods, of $\Sigma(nh) = 170\,520$ wagon-hours.

[656 .25 (47)]

Automation on the Russian railroads.

Translated by N. Petroff,

Senior Electrical Engineer, New York City Transit Authority, from the Russian periodical, « Railroad Transport ».

(*Railway Signaling and Communications*, August 1960.)

Because the signal engineer, perhaps more so than anyone else on the railroad, will be involved in the techniques of automation, we present this article here.

At present only a few methods of automation are employed by the railroads but in the future much wider use of automation is expected. Quite a few scientific establishments and universities are involved in the development of this equipment. For instance, problems of automatic operation of cars in classification yards and problems of automatic operation, acceleration, and braking in mountainous regions are being studied by government institutions. Of course, the best solution would be to develop something that will perform the functions that human beings are performing.

Automatic operation leaves to the human element only the function of following up the equipment of the « automatic motorman ». Unfortunately, such equipment has not yet been developed, equipment that could be substituted for a human being's eyesight and hearing; equipment that could realize the conditions of the track occupancy ahead of the train, aspects of the signals, and acceleration or retardation.

This new equipment must satisfy the following conditions :

Prerequisites.

1. It should insure movements of the trains according to schedule.

2. It should provide the most economical operation, insofar as speed, safety and loading are concerned.

3. It should control the acceleration and retardation according to the demands of wayside signaling.

4. It should have, at all times, complete check on the application of energy and application of brakes to the locomotive.

Safer, more economical operation.

If the above functions are performed by the « automatic motorman », very little will be left for the human motorman to do. Much safer operation will be accomplished and the operation prescribed by automatic equipment, closely following train graphs and providing for the most economical way of applying the motive energy, will result in reduced cost of transportation.

In actual operation of the railroad, the weight of the train, train resistance and the characteristics of motor equipment and braking equipment seldom correspond to the theoretical data, and as a result, deviations of actual train movements from those prescribed by the train graphs will develop. In addition, unforeseen emergency stops and reduced speeds will also result in deviations from prescribed data. It is the experience of the motorman which compensates for bad conditions and keeps the trains running. With automatic equipment, corrective measures could be taken by the equipment automatically with greater precision than is possible with the best qualified motorman.

The amount of energy used by the train, to a great extent, depends on the experience of the operator. With automatic equipment the most economical speed, resulting in a saving of fuel, would be prescribed and lower costs will result. Present day techniques of automatic controls are closely associated with high speed computing machines. In simple form, automation could be presented as in the block diagram of figure 1.

Keep speed at predetermined level.

In the process of train movement, comparison of actual speed of the train with that prescribed by the graphs is continuously maintained. If a deviation of speed occurs, the automatic equipment performs the necessary changes in controls to keep the movements of the train within the prescribed limits of the schedule. It is not expected that the automatic equipment will bring the train back on schedule if some unforseen emergency stop or reduced speed occurs. This defect could be partially compensated by the use of the curve $t = f(s)$, time-distance curve, and the curve $v = F(s)$, speed-distance curve. By so doing, « automachinist » (automatic equipment) will direct the movement of the train with respect to the schedule.

Modern locomotive controls are generally provided with a few steps of control, but should be provided with a much greater number of steps for smoother operation by automachinist. With an insufficient number of steps, automachinist will be unable to maintain the schedule because the disagreement between the actual speed and prescribed speed could not be eliminated.

Compensate for lost time.

Introduction of the element of time into the calculator will provide automachinist with an additional factor to compensate for these shortcomings. Automachinist will be able to maintain the schedule more readily, if in addition to the requirements of speed, the factor of predetermined time of arrival at destination is also introduced. The use of high speed computers in the automachinist equipment will greatly simplify the problem.

The incoming data of distance covered by the train, its speed, time, profile and grade, and signal aspects are fed into the incoming block of the automachinist, all in a form readily usable by the computer, which is the main part of the automachinist. It is the computer which selects the required controls based on information fed into it. It is the computer which selects controls for moves on schedule and with the least amount of energy expended. The outgoing block collects all data evaluated by the computer and formulates it in definite requirements of locomotive controls.

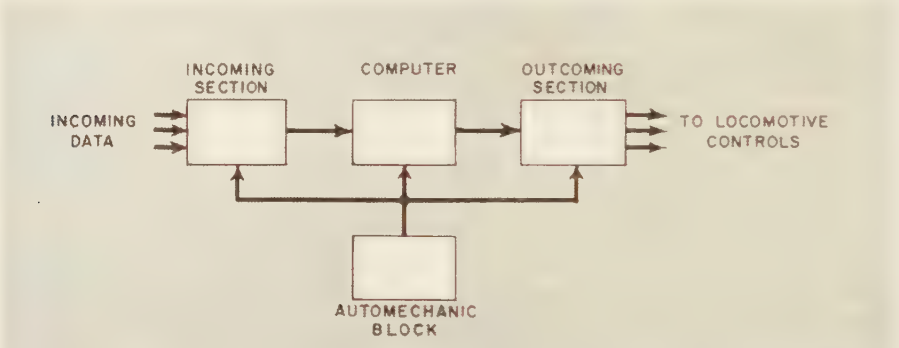


Fig. 1. — The simplified block diagram of the automatic controls now under test.

Step by step evaluation.

As an example, let us follow automachinist in selecting the controls. Assume that at a certain moment the train operates on the first point of control, according to requirements of lowest amount of energy consumed. Based on this characteristic, on theoretical speed and length of the block of track ahead, the computer foresees a

late arrival at destination. Immediately the computer seeks another solution, using the same incoming data as before, but with a proposed change of controls to the next higher point of the locomotive motor control characteristic. All this time the train is still driven with previously determined controls. If the result of the second computer evaluation is still « arrival late », the computer seeks the next solution on the third point of characteristic of motor control. At the same time, the computer sends out the change of controls to take place in the locomotive to switch to the second characteristic.

If the result of the third evaluation reveals that the train will arrive at the destination ahead of schedule, the third evaluation will continue to circulate and repeat evaluations with changing data as movement of the train progresses, such as speed, distance, time, etc. When calculated time approaches the assigned time the automachinist sends the appropriate requests to the controls of the locomotive.

In this fashion a continuous attempt is made to keep the train movements on schedule even if time was lost on an emergency stop or reduced speeds. The computer also could be fed with data requiring reduced speeds on portions of the track where it was deemed necessary. Generally speaking, both types of computers, digital and analog, could be used. But locating electronic computers on locomotives is not desirable because of the short life of electron tubes, susceptibility to vibration at high speeds and accelerations, and unreliability for the precise type of work required. The better type of computer is one using magnetic cores.

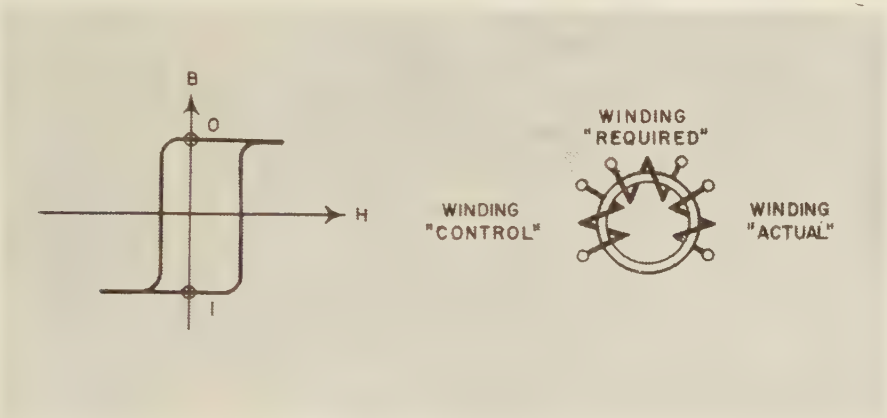


Fig. 2. — The magnetic cores proposed for use in the computer have a rectangular hysteresis loop. The material changes magnetic polarization rapidly and is easily saturated.

Magnetic core computer.

The calculating block of an automachinist will consist primarily of magnetic rings, 3 to 7 mm in diameter, possessing rectangular hysteresis loop characteristics (figure 2). The magnetic rings are supplied, as shown, with three windings through which electric currents are passed to compare the required data, the actual data, and the data for the controls.

Elements of the magnetic loop could be in either one of the two stable magnetic conditions, marked on figure 2 as point « 0 » and point « 1 ». With current in winding «required», loop passes from condition « 0 » to condition « 1 », and with current in

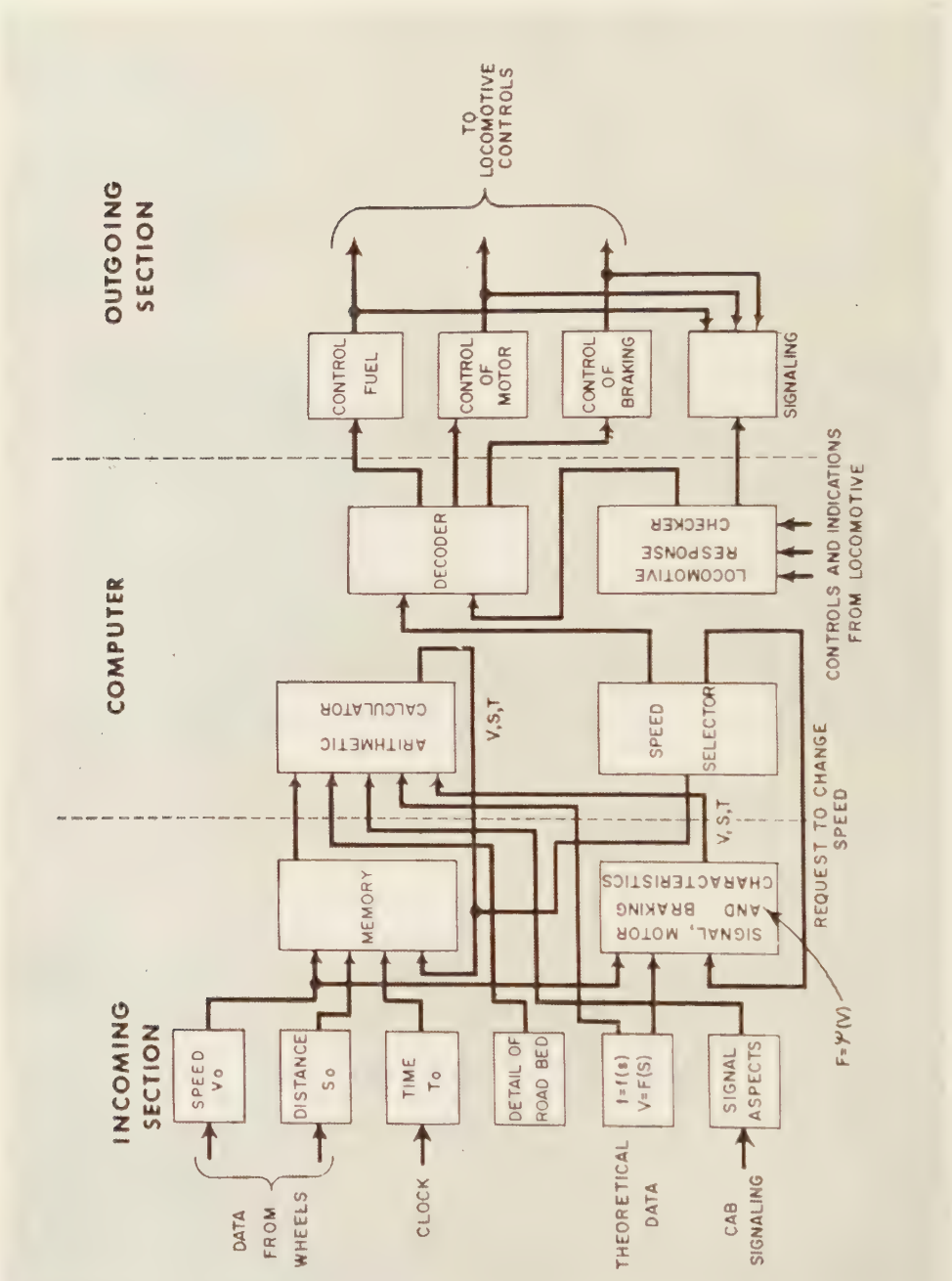


Fig. 3. — Illustrates the flow of information through the various components of the « automachinist ».

winding « control » from condition « 1 » to condition « 0 ».

It is very easy and simple to enter any information into the computer in the form of numbers. For instance, the three aspects of the wayside signal could be represented with three numbers : red = 0, yellow = 1, green = 2 and assigned to two rings in the form of binary numbers : 00, 01, 10 (a binary number is a number in the system based on the number 2).

The scheme of the automachinist making use of a digital computer (figure 3), is as follows : Incoming data in binary form is fed into several separate blocks. The speed and distance covered by a train are obtained from the wheel rotation, the diameter of the wheel, and the time of read out, and expressed in binary form on the proper scale. The other blocks will also interpret their respective data in binary form. *

To determine the time the train is at a certain point on the road, the basic equation of motion would be used, together with other factors related to the requirements of the most economical way of train control. These equations are solved in the computer, with the data fed into the incoming portion of the automachinist.

The equation of the train movement is usually represented in the form of differential equation of the second order :

$$\frac{d^2s}{dt^2} = A \frac{F_k - W_k - B_k}{P + Q}$$

where :

F_k = the force of pull of the locomotive in kilograms;
W_k = total train resistance in kilograms;
B_k = braking force in kilograms;
P = weight of the locomotive in tons (1 000 kg);
Q = total weight of the cars and load in tons;
A = acceleration in kilometers/hour/hour due to a force of one kilogram applied to weight of one ton.

The computer will calculate the speed, distance and the time. The obtained solutions will be compared with those required by the graphs and the required control will be applied to the locomotive. At the same time the computer will determine the most economical control from the point of costs of energy.

The most convenient types of locomotives suited to automechanic controls are electric and Diesel locomotives. They have a centralized and not too complicated system of control. Application of automechanic on electrified railroads may result in considerable energy savings.

At present, the Pensenski Railroad is conducting tests of automation. Tests of automachinist on the Kubichev-Besimianka Railroad indicate that the automachinist responds faultlessly to signaling on block control territory, selects the most advantageous speed and braking, and takes into account the profile and alignment of the roadbed and the load of train, continuously performing the required computations.

Automation will improve the use of existing locomotive equipment and improve average speed of operation. It will result in a saving of energy used by 5 to 7 %, and improve the capacity of the road by 15 to 20 %. At present the Leningrad Institute of Engineers of Railroad Transit is developing the automachinist for steam locomotives. The next improvement of the automachinist should be equipment to respond to the same stimuli as a human being's senses of eyesight and hearing. Research in the development of mechanical models of organs for eyesight and hearing and the necessary transmission of these sensing processes is under way in many research laboratories and universities. It could be said assuredly, that the task of the machinist (engineman) on the railroads will be ligthened more and more quite soon.

(*) Editor's Note. — It is assumed that the measurements will be made using an idler wheel, or a special small wheel for the purpose, to avoid errors due to wheel slippage.

[656 .25 (73)]

How to plan for microwave.

(*Railway Signaling and Communications*, October 1960.)

When planning for microwave three major areas should be carefully considered: 1) *advantages and disadvantages of microwave vs. open wire line and cable systems;* 2) *economic considerations; and* 3) *engineering considerations.*

The following article summarizes a report presented at the recent Communications Section, AAR, meeting by its Committee 4, Radio and Allied Communications. The report was prepared by R. C. Karwatt, director of communications, New York Central; with contributions by L. R. Thomas, superintendent of communications, system, Santa Fe; L. E. Kearney, communications engineer, Association of American Railroads; and C. J. Nelson, assistant superintendent communications, engineering, Rock Island.

A properly designed microwave system has been proved to be more dependable than wire line systems. The microwave system has far greater immunity to adverse weather conditions. Heavy icing conditions will cause wire breakage or complete collapse of a pole line. The time required to put a wire system back in service under these conditions is very lengthy.

The wire line system running through open country for many miles is subject to many types of man-made interference. This interference may be caused by electrical machinery operating in the vicinity of the wire line. It may be caused by inductive interference from other lines, or it may be caused by atmospheric interference due to the effects of lightning discharges. The microwave system is far less subject to man-made interference and atmospheric interference.

The wire line is highly vulnerable to damage by construction forces working in the vicinity of the line. It is also subject to accidental damage by vehicles and trains. Insulators on pole lines have been an attractive target and, therefore, highly susceptible to malicious damage. The microwave system is free of this problem.

Most of the items which affect the dependability of the communications system also affect its quality. The microwave system has inherently greater band width and smoother frequency response. The microwage system being essentially free from external effects will provide a higher quality signal. The transmission path in the microwave system has little effect on crosstalk and/or distortion in a voice channel. The wire line system is susceptible to crosstalk and/or distortion because of changes in line characteristics. The flat response of the radio base band produces superior individual channel response.

Microwave systems are inherently large capacity systems. The cost of increasing the band width of the radio equipment from a few channels to many channels is not great, and for this reason most microwave equipments are designed to accommodate a large number of channels. A wire line is generally constructed to provide the required number of circuits.

The greatest capacity of normally used wire lines is approximately 16 channels. The capacity of a microwave system may be as high as 600 channels with most systems having a capacity of 120 to 240 channels.

With the radio system it is merely necessary to add additional channelizing equipment to obtain a greater number of circuits. With a wire system, expansion will generally involve transposition of lines or the addition of new lines. Another advantage of the microwave system is the

ability to handle broad band channels. This ability is particularly important when it is desired to transmit high speed information or high speed facsimile.

Maintenance is concentrated.

Maintenance of the microwave system is concentrated at a limited number of locations rather than dispersed over the full distance of the system, as it is with wire lines.

The location and clearing of trouble is facilitated in the microwave system by the supervisory and alarm facilities which may be built into the system. Standby radio equipment permits improved scheduling of maintenance activities. Built-in test equipment can be provided to speed up the analysis of troubles.

Hot box and dragging detector units, and other protective devices can conveniently be connected through channels of the microwave system to central points. The high microwave towers increase the coverage of the VHF radio, and permit the installation of fewer stations to cover a given area. VHF radio can be remotely controlled over channels of the microwave system.

Emergency power sources are usually provided at microwave locations and these same sources can be used to power other equipment, thus increasing their reliability. The buildings can also be used to house additional equipment. The concentration of all this equipment in one location improves their maintenance.

Disadvantages of microwave.

One of the disadvantages of the microwave system is that it is difficult to provide direct service to some local offices, pole boxes, booths or signal equipment. This difficulty can be overcome by the use of short sections of wire to serve local offices.

In some cases it may de difficult due to terrain to reach a desired drop out point directly from the main microwave trunk. This can be overcome through the use of a microwave spur or by the running of wire and cable between the microwave station, and the desired drop out point.

Specialized test equipment will be required for the maintenance of the carrier system (because of the greater band widths involved), the microwave radio equipment and antenna systems.

Prior to the installation of the microwave system, a construction permit must be obtained from the Federal Communications Commission before any work may proceed. In addition to the construction permit a license to operate the system must also be secured. The construction and use of wire lines are not subject to government restrictions.

It is necessary during the design phase of a microwave system to consider the frequency allocation plan. Not only does this involve the proper selection of frequencies within the system, but also an investigation of the use of frequencies by other users in the general area in which the system is to be installed. This involves greater study than that normally associated with the construction of wire lines.

Economic considerations.

The railroads have extensive existing wire plants, and a comparison of the costs to install a microwave system is complicated by the existence of the wire plant. The initial installation cost of any system will be a function of the number of channels in the system length. To make a cost comparison of two systems an elimination of all factors common to the systems compared will simplify the problem considerably.

When comparing any two systems, operation of the terminal equipment will be identical for both systems. The same number of channels will identically be terminated on the switchboard, and operated by the same number of operators.

When comparing a multiplex channel radio (microwave) system with an open wire system, the radio system cost will include the terminal carrier multiplex system,

the intermediate relay stations, the terminal radio stations, power equipment, etc., which are not required for an open wire system.

When comparing a multiplex channel radio system with a cable carrier system, since both systems require terminal carrier multiplexing equipment, their costs will not be included in either system. On the other hand, the cable system will include the intermediate carrier repeater equipment which is not required in a through-radio multiplex system.

It is possible that a system with a low initial cost may have a higher annual and a higher actual overall total cost than a system with a comparatively higher initial cost if the salvage valuation, depreciation and maintenance costs are higher. Therefore, to obtain a true economic picture of a given system, cost comparisons must include, not only the initial costs, but also the comparative annual operating costs and the actual total cost over the entire expected life of a given system. To obtain the true annual operating costs, material and labor must be multiplied by: 1) the interest on invested capital; 2) depreciation, and 3) maintenance costs.

The initial cost of an open wire system should include the line survey costs, the cost of the right-of-way for the pole route, cost of the poles, cost of wire and fittings and the labor on each of these items.

To arrive at the cost of a cable system, the estimate should include the line survey cost, the right-of-way costs, the cable trench opening and closing, cable laying and man-holes for an underground cable and the cost of poles, erection and installation, if the cable is of the aerial type. The cost of repeater stations, loading cases and repeator equipment is required.

Microwave system costs.

The microwave system cost components are survey cost including engineering and transportation, the costs of land, buildings and roads, the costs of towers and antennas, the cost of radio equipment, the cost of power equipment and the cost of various accessory items, such as the provision of power, fences and housing. The annual operating charges contain the same factors regardless of which system is employed. These include amortization, interest, taxes and maintenance charges.

For estimating purposes, amortization, interest, taxes and maintenance can generally be applied as a percentage of the total initial cost of the system. The maintenance cost factor will vary with the various items which comprise the system. For example, the maintenance cost of station buildings, of towers and antennas, of power equipment, of radio equipment, of carrier wire lines, wire line repeater stations and repeaters.

The typical railroad case involves either the requirement for additional circuits or replacement of existing circuits. The present cost of operation of the existing plant should be determined. Any savings in maintenance or operation through the installation of microwave should be subtracted from the present costs. The microwave costs should then be added to determine the composite cost.

The addition of microwave will generally result in the removal or salvage of some part of the existing plant. The net salvage value of the plant will reduce the amount of capital required for the new facilities. The cost of the combination wire and microwave system may then be compared with the cost of an all wire system.

In calculating the cost of the all wire system, the line survey cost and cost of right-of-way for the pole route will not be a factor unless the wire line route for the new section is not the same as the original route. It may be necessary to compute the costs of poles as the additional facilities may require strengthening of the pole line.

Where the addition of a large number of channels is required, it can be shown that the microwave system cost will be lower than that of the wire line system. For smaller numbers of channels, particularly where transposition of existing wires is not required, the installation cost of the

wire plant may prove to be less expensive than that of the radio system.

Considering all factors, the maintenance costs will generally be lower in the case of the radio system. The intangible advantages in the form of expansion capability, flexibility and ability to handle high speed data and facsimile must also be weighed when making this comparison.

Engineering considerations.

A simple line diagram of the proposed system should be prepared first, showing as much detail on it as is practical, indicating for each circuit the type of service, termination at each end, type of signaling required or special considerations such as may be used on alarm and supervisory channels, or radio control channels.

In planning a microwave system, it may be beneficial to retain portions of an existing pole line with reduced wire facilities to provide local telephone and telegraph service to smaller stations and to intermediate locations for signaling without providing drop out and insertion facilities at each repeater.

Alarm and supervisory channel is normally used by maintenance and supervisory personnel for normal maintenance purposes and is dropped at each repeater and is provided with selective calling or ringing of each point. In addition each repeater can automatically report a number of alarm conditions to a central point.

Radio control channels may be provided over a single voice channel with insertion and drop out at each repeater where a base radio station will be required to provide adequate coverage to mobile units over the entire area, or a separate voice channel may be utilized for each base station from the dispatchers location.

Trunk voice channels are normally two wire drops connected at each end to switchboards. They are provided with 20-cycle ringdown, if used between manual switchboards, or E & M signaling if used between automatic switchboards.

Local voice channels: it may be necessary to extend beyond the microwave or pick up between repeater points local way stations and pole boxes for dispatching or conversation purposes.

Trunk printer or Morse circuits may be placed together within a voice channel or a number of voice channels, or should be capable of being operated as speech plus duplex for possible extension over open wire carrier along with the associated voice channel to some other location. These circuits may be either half or full duplex as required, and should be capable of being extended over carriers or standard duplex equipment.

Local printer or Morse circuits: party line operation with drop out and insertion of telegraph signals at numerous intermediate points on a microwave system is normally very difficult and expensive. It is suggested that consideration be given to handling messages to smaller offices by telephone and trunk printer circuits to the larger offices.

CTC and signaling channels normally consists of a voice channel with one or more duplex telegraph channels. Channels for special services may be required for data transmission, facsimile, closed circuit TV, etc. It is suggested that these applications be reviewed thoroughly to determine feasibility, and that the base band to be provided by the microwave will be capable of handling the wide band widths that are proposed with the degree of reliability demanded of this type of service.

Consider propagation factors.

Microwave energy travels in nearly a direct line. However, the line of sight path between transmitting and receiving antennas must have additional clearance, known as the Fresnel area, which is further divided into zones. The boundary of the first Fresnel zone consists of all points along a path having a length of 0.5 wave length greater than the direct path. In practice it has been found to be satisfactory if 0.6 of the first Fresnel zone is clear of obstructions.

In the lower atmosphere, temperature and water vapor pressure normally decrease with increases of altitudes. This results in a decrease in the index of refraction causing the microwave beam to travel at slightly greater velocity at the higher altitudes, producing a downward bending of the beam effectively increasing the radio horizon. The same effect would be obtained if the earth's curvature were reduced. This effective reduction in earth curvature is expressed by the equivalent earth radius factor (K) which is equal to 4/3 in a standard atmosphere. However, in profile plotting for 6 kmc paths it is accepted practice to use (K) true earth radius (K = 1.0).

Changes in the index of refraction causing beam bending has the effect of changing the amount of path clearance causing changes in the received signal strength. A reduction in clearance will result in attenuation of a received signal. The depth of fade from this effect may be reduced by increasing the path clearance.

The combination of irregularities in the atmosphere will cause more than one propagation path to exist between the transmitter and the receiver. Each of these paths traveling over a different route will have a different length. If all of these signals arrive in phase, there will be an improvement in the received signal. If they arrive out of phase, there may be cancellation and the received signal will fade. This type of fading is known as multi-path fading. Reliability against this type fading is obtained by providing an excess of received signal strength or fade margin.

The attenuation effect of precipitation at 6 kmc is so slight that additional fade margin is not usually required, since precipitation is normally accompanied by winds that prevent stratification and attenuation fading.

Reflection considerations.

On most microwave paths the received signal is composed of a direct wave and an earth reflected wave. These two signals may either add to or subtract from each other, dependent upon their phase relationship at the receiving antenna. When the microwave path spans an efficient reflecting surface, such as a body of water, smooth terrain, or salt flats, the reflection coefficient may approach unity and cause heavy cancellation and reinforcement. The reflected signal undergoes a 180-deg phase shift at the reflection point. The addition of the direct and reflected rays will vary with the height of the receiving antennas. If both the receiving and transmitting antennas are of equal height with respect to the reflecting surface, the reflection point will lie in the geometric center of the path. In most cases, however, the reflection point will lie somewhere between the station with the lower antenna elevation and the middle of the path. The specific point of reflection will move back and forth with changes in the refractive index.

In general, microwave paths with highly reflective terrain are undesirable and should be avoided when possible. The high-low siting technique, where one site is highly elevated to provide the necessary path clearance and the other site is located near the level of the terrain, will assist greatly in the solution of this reflection problem.

Types of noise.

Receiver thermal noise includes the noise generated by the resistance that the antenna system presents to the receiver input plus thermal noise generated in the « front end » of the receiver. Microwave receivers operating in the 6 kmc band have noise figures of 10 to 15 db.

Amplitude or phase distortions in the radio equipment occurring when the system is modulated will produce intermodulation noise. The amount of intermodulation noise is dependent to some extent upon the level of the modulating signal. Increasing the level will overcome the effect of thermal and intrinsic noise, but may create a greater amount of intermodulation noise.

Distortion of the direct wave by the reflected wave will cause path distortion noise which appears in the system as intermodulation noise.

All radio equipment has a characteristic of derived channel signal-to-noise ratio versus received RF signal level. The received signal level of a well-designed system during normal propagation conditions, and assuming no fading, will be high enough to place the operating point above the minimum channel noise portion of a noise characteristic. Under these conditions the noise characteristic will be determined by the amount of the intermodulation.

The system should be designed in such a manner that the desired level of noise power is only exceeded for less than one per cent of the busy hour. Receiver thermal noise is the controlling factor, and the channel noise is a direct function of the amount of fading. At the threshold point the noise increases so rapidly with lowering of the signal that satisfactory operation is no longer possible. When specifying the channel noise objectives, it is, therefore, important to define the per cent of time that the signal-to-noise ratio should remain above one or more specific values, and to define the fading margins required for system reliability.

System reliability is directly related to fade margin. In a path with adequate clearance, fading is generally of the interference type. A fade margin of approximately 40 db should be provided for in systems which do not use diversity. Fade margin may be reduced by approximately 10 db in diversity systems.

Types of diversity.

Interference fades usually vary with operating frequency and the physical path characteristics. Even with close frequency spacing and almost identical paths, the signal will not fade to the same depth on each path simultaneously. The application of diversity receiving systems will tend to flatten the fading characteristic, and result in an improved signal-to-noise ratio during the periods of fading.

The improvement in propagation reliability through the use of frequency diversity is dependent upon the frequency separation of the two radio systems. A separation of approximately 5 % of the lower radio frequency is required for maximum improvement. This separation is difficult to obtain in practice, and a 2-3 % separation is more common. Frequency diversity is now approved only after proving definite need through actual operating tests for each hop requested.

Spacing of the receiving antennas will have an effect equivalent to that of spacing the frequency of the RF channels. This is true in the case where the antennas are either placed one above the other or side by side. The antenna separation required for effective space diversity is such that the difference between the length of the reflected path and the direct path is approximately equal to one-half wavelength. On the average path the separation will be about 200 wavelengths or approximately 50 ft.

Survey and site selection.

A preliminary microwave paper survey is usually made to determine the number of repeater stations and approximate tower heights required. From this information the preliminary cost estimate can be made. The final field survey assures reliable microwave propagation between all stations and establishes the exact site locations and other information required for the filing of FCC construction permit applications.

Contour maps of most areas of the U.S. are available from national, state and county agencies. Aeronautical charts are useful as a source of information in arriving at the general route. Microwave terminal and repeater locations should be plotted on the available maps. Elevation data should then be taken from each map and plotted on the profile chart.

Following the map study, the field survey must be made. Three methods can be used to determine path clearance : optical, altimetry or aerial. Many times the clearance of a path can be verified by visual sighting from one end to the other with

the aid of a pair of field glasses or a telescope. Greater accuracy can be obtained with the use of a transit. When visibility is poor and it is not possible to sight directly with optical instruments, clearance may be checked during the day through the use of a flashing mirror, or at night through the use of lights. These methods are not very precise and should be supplemented by checking the altitude of prominent features by means of an altimeter.

The altimeters used in path survey work should be of a precision surveying type of high accuracy. Accuracies in the order of 5 ft. can be obtained through the use of these instruments. Two altimeters should be used, both instruments adjusted to the known elevation at a bench mark location. One altimeter should remain at this point, and the other altimeter taken to the point desired to be measured. Readings of temperature and elevation should be recorded at each point.

The aerial methods include running profiles by radar surveying from the air, and taking stereoscopic photographs of the area being surveyed. Both methods are accurate (can provide profile reliability in the order of $\pm$ 5 ft. over an entire path), but are expensive.

The field survey should not be limited to the attaining of information solely for the purpose of plotting profiles and detailing path clearances. It should include the collection of all information on accessibility, power availability, soil conditions, site obstructions, availability and cost of land, existing structures, availability of suitable alternate locations, zoning regulations, airports, unusual weather conditions.

RF equipment considerations.

The best radio equipment for a particular communications system should be selected, based on a consideration of the characteristics of the baseband, the amount of radio gain available, operating frequency band, and required frequency spacing between radio channels, primary power requirements, supervisory functions available, equipment reliability and provisions for maintenance and testing. A given system may include terminals, through repeaters, drop repeaters and terminal repeaters.

To achieve maximum reliability standby RF equipment should be provided. In the complete standby system, standby equipment is provided for all units. With cold standby the system will be interrupted until the tubes have been heated and power developed. The interruption may be in the order of minutes. Hot standby equipment may take two forms, either the filaments of the tubes may be heated, or power may be developed and fed to a dummy load. Through the use of hot standby, the delay may be cut to milli-seconds. Diversity provides the maximum degree of reliability. In this case there is no interruption due to failure of one of the RF equipments, as both the equipments are in operating condition at all times.

A variety of methods may be used to combine several transmitters and receivers for parallel path, diversity or standby operation on a single antenna system.

Antenna systems.

Lower power transmitters can be used at frequencies in the 6 kmc range because high gain antennas are available. Gains of 35 to 45 db are not unusual for antennas at reasonable cost.

In almost all cases a parabolic antenna is used because of its low cost and light weight. The parabolic antenna consists of a feedhorn of waveguide with a small horn or end piece arranged to radiate the energy from the focal point into a parabolic reflector. Parabolic antennas may be heated where required to prevent the formation of ice. Radomes may be used to cover the antenna to prevent nesting of birds, collection of leaves or dirt, or damage to the feedhorn.

Where large antenna heights are required, an antenna and reflector are generally used instead of a long waveguide run. The antenna is mounted on the roof

of the equipment building and the reflector at the top of the tower slanted about 45 deg to the line of propagation.

Where a direct microwave path cannot be established between two points because of some geographical or man-made obstacle, it is sometimes possible to establish a path by way of a passive repeater. Passive repeaters fall into two general categories; two parabolic antennas connected back to back through a short piece of waveguide and a flat or « billboard » type reflector which acts as a mirror to reflect the direction of the beam. Passive repeaters are only practical under certain specific conditions. The point at which the repeater is located must permit adequate path clearance to each of the terminal points. The repeater must be located near one of the end terminals. The flat of « billboard » repeater must be located so that the geometry of the terminal and repeater stations gives a small reflection angle.

Two general types of transmission lines are employed to connect the radio equipment to the antenna system : coaxial cable or waveguide. Waveguide may be used at either 2 000 or 6 000 mc, although coaxial cable is normally in use at 2 000 mc. The most commonly used waveguide is the rectangular type (WR 137). This waveguide is constructed of various metals, including copper, brass, and aluminum with internal coatings of silver or gold. The recommended type is oxygen free, high conductivity copper. The attenuation of this waveguide is approximately 2 db per 100 ft. It is relatively free of internal corrosion when pressurized with nitrogen or dry air. The WR 137 waveguide is available in many pre-formed shapes, such as curved and twisted sections. Flexible waveguide may be used to make difficult bends and to facilitate antenna alignment. The loss in flexible waveguide is approximately 0.1 db per foot and its use should be held to a minimum.

Guyed or self-supporting towers may be used for the mounting of antennas or reflectors. The factors which will generally determine the type of tower are the availability of land and local zoning regulations. For tower heights in excess of 100 ft., self-supporting towers become extremely expensive. The tower specification must include rigidity and twist requirements under varying wind and ice loadings. Tower twist allowance should be such that the beam is not permitted to exceed one-half the beamwidth of the antenna or one-quarter the beamwidth of the antenna system if a reflector is used, under the maximum rated wind loading conditions. All towers should be painted in accordance with applicable government regulations.

Flashing beacons and/or obstruction lights must be provided where required by government regulations.

Power requirements.

The absolute reliability of the microwave system is dependent upon the supply of power to the radio equipment. Commercial power is rarely subject to complete continuity of service. Interruptions may be expected in every locality. To prevent a power failure from disrupting the system, standby power should be provided.

Automatic delayed starting generating plants powered by either gasoline, Diesel, or gas are available. This type of plant will introduce an interruption in service of a minimum of 10 sec, and greater interruption time may be expected. To eliminate the break in service an immediate type of standby generator may be employed.

Batteries may be used as standby power for the critical items of equipment. When batteries are used, they should have sufficient capacity to maintain the equipment operative for the maximum length of time that it will take for the commercial power to be restored.

Commercial power is subject to voltage fluctuations in most areas. To assure optimum performance, voltage regulators should be employed. Magnetic amplifier types are more reliable than vacuum tube types, but they are sensitive to frequency variations.

Adequate grounding systems must be provided to protect towers, buildings and equipment. Power and communications

lines should be furnished with protection.

Buildings may be prefabricated or unassembled, metal or masonry. Sufficient space should be provided to allow for expansion or the installation of additional facilities. The roof should be capable of supporting the antenna fixture and snow and ice loads.

All openings provided for ventilation should be covered with screens and filters to prevent the passage of insects and dust into the building. Fans should also be used during the summer to maintain the temperature inside the building as close to the outside ambient as possible.

To prevent damage to the building or unwarranted entry, the building area, including the tower base, should be enclosed by a fence. When guyed towers are used, the entire area occupied by the tower base plus guys need not be fenced. Instead it may be sufficient to place a fence about the guy anchor at sufficient distance to prevent the guys from being struck by vehicles or animals.

FCC authorization required.

Under present rules of the FCC a construction permit must be obtained for each location at which a microwave transmitter is to be installed. A separate application (FCC Form 400) is filed for each transmitting location. In selecting the particular frequencies to be entered on FCC Form 400, it will be necessary to obtain information with respect to other microwave systems operating in the area of the proposed system. A joint group was formulated primarily for this purpose in 1954 which is known as the Operational Fixed Microwave Council. The Communications Section, AAR, is a member of this council. The council has assembled information on all operational fixed microwave stations presently authorized and the route of these microwave systems has been entered on maps.

In applying for a microwave system, it is important that a functional diagram be submitted in as complete detail as possible. It is not necessary, however, to duplicate such a diagram for each station in the system. Instead, the diagram may be attached to the application covering one of the terminal points and reference to this fact made on the applications for repeaters and for the other terminal point.

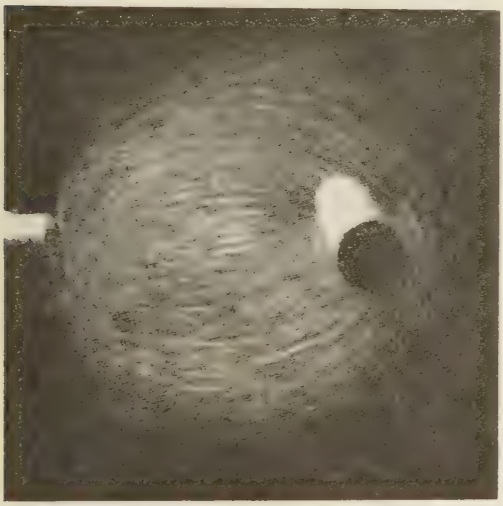
After construction permits have been received and construction completed, FCC Form 400 must be filed with the Commission in order to obtain a license for each station.

Safety comes to electrostatic spraying.

(*Engineering*, 23 September 1960.)

Electrostatic paint spraying is economical both in time and materials. The Felici electrostatic generator makes the process safe and cuts the capital cost.

The advent of the Felici electrostatic generator, with its flat voltage/current characteristic, its inherently safe method of operation and its small size, might well

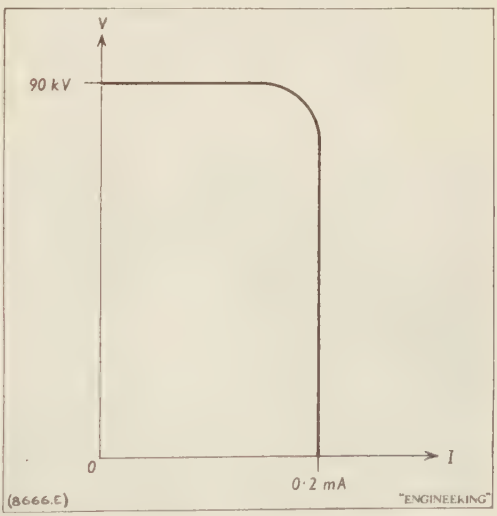


The paint wraps all round the object.

revolutionise the paint spraying business. The first equipment to use this generator is the Statron developed by « Société Anonyme de Machines Electrostatiques (SAMES) », of Grenoble, France.

The Statron comprises an electrostatic generator producing 90 000 V, an atomising spray gun with an adjustable output up to 5 gallons of paint per hour and a feeding system for the paint. This feeding system may be based on a gravity tank situated above the gun, a paint cylinder connected to a source of compressed air, or simply a small paint pump.

In operation, paint at a pressure of about 10 lb. per sq. in. is delivered to the spray gun, which weighs 12 oz., together with electrical power at 24 V and 90 000 V; the lower voltage being used to drive a small electric motor incorporated in the gun and the higher voltage to charge the paint. The paint is led to a cylindrical cup which is rotated at 3 000 r.p.m. by the motor, and the electrically charged paint then spins out of the end of the cup in an atomised spray due to the centrifugal force imparted by the revolving cup. The electrostatic field which is present also assists in the atomisation of the paint. Charging of the paint (negatively to 90 kV) helps in the dispersion because particles are similarly charged and hence mutually repellent. Thus, the spray gun produces a cloud



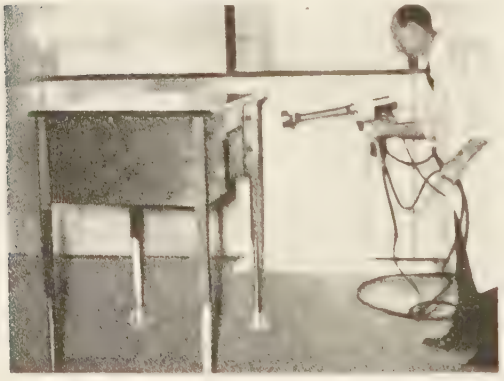
The voltage-current characteristic.

of finely-dispersed negatively-charged paint particles which are attracted to any earthed object in their path.

In the great majority of cases this cloud of paint will cover all sides of an article merely by spraying towards one face of the article. It will cover the surfaces of the nooks and crannies of an object without any particular effort or skill on the part of the operator — indeed, a first class spraying job can be done by unskilled labour after only a few minutes instruction. The main advantage, however, is probably the fact that overspray is virtually eliminated.

Object	Time saving, per cent	Material saving, per cent
Tubular articles, i.e., tubular furniture	60	75
Gratings and wire mesh fencing	80	85
Scaffolding	60	65
Angle sections	40	60
Large water heaters	-	60

A survey in Germany produced the figures for savings of time and materials using the Statron which are shown in the accompanying table.



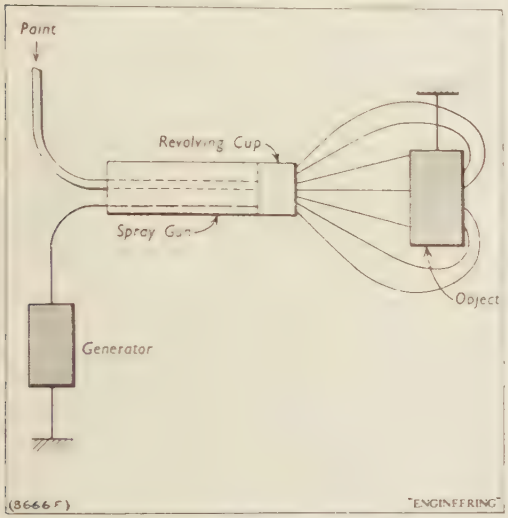
A wide range of materials can be sprayed.

It will be appreciated that the Statron can be used to spray any material which is an electrical conductor, even in the mildest way. To the indiscriminating paint, then, the operator being earthed represents just as good a target as the work and it is not impossible for him to spray himself. This is why the gun, shown in the accompanying illustrations, is fairly long to keep the paint away from him. So long as the gun is kept near the work when it is operating, 6 in. is about the average, there is no danger of anything untoward occurring.

Overspray is eliminated.

The charge is imparted to the paint in the spinning cup which is connected to the electrostatic generator and insulated from the rest of the gun. This means that the specific resistance of the paint must be high in order to prevent too much current running down the paint line to earth. It is recommended that the specific resistance should be between the following limits: 2×10^8 and 5×10^7 ohm. cm. The specific resistance of a paint can be adjusted to a satisfactory value by adding one solvent or another — for example, alcohol decreases resistance and petrol increases resistance. The upper limit of the specific resistance is fixed in order to facilitate

transmission of the charge to the paint. If the resistance is too high, it is difficult to charge up the paint particles. The only paints which cannot be used with this equipment are those containing water. This is because of their high conductivity.



Schematic diagram of the circuit.

The electrostatic generator is housed in a metal box measuring approximately 26 in. by 13 in. by 11 1/2 in. and which weighs about 13 1/2 lb. The short circuit current of the generator is 0.2 mA. This is well below the lethal dose and the equipment can be earthed to the human body without discomfort or danger.

Each gun is supplied with four atomising heads of different sizes. Selection of the head is determined by the amount of paint required from the gun — the smallest, 50 mm diameter, nozzle sprays between 4 and 6 litres an hour, and the largest, 100 mm diameter, nozzles gives 25 to 30 litres an hour.

The considerable savings in man-hours and materials should make electrostatic spraying very attractive indeed to anyone who does a lot of spraying. There must be many large-scale applications for this equipment where fixed installations using one or more Statron units could speed up the production flow and cut material losses to a negligible amount. An excellent example of this is the motor car industry where bodies could possibly be sprayed in a fraction of the time now taken without the use of skilled labour and saving many thousands of pounds per annum in paint wastage. In addition, less floor space would be required and rejects could probably be reduced.

So far as operator health and his working atmosphere are concerned, the usual problems are reduced by electrostatic spraying. There is no paint fog and ventilation is required only to remove solvent vapours.

The Statron is being marketed in the UK and Commonwealth by Aerostyle Limited, of Sunbeam Road, London, NW 11.

[621 .131 .1]

Rail surfaces and locomotive wheel slipping.

(*Engineering*, 2 September 1960.)

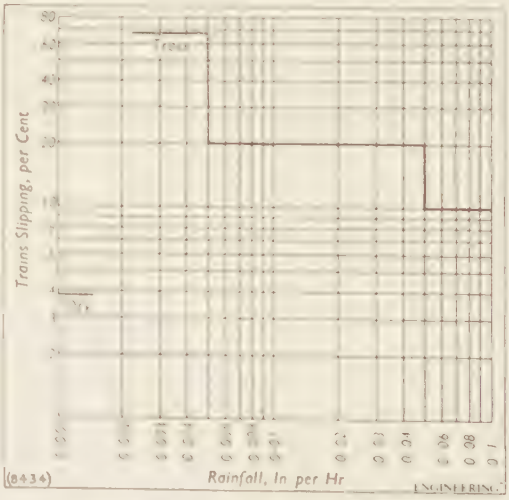
With a branch line of the Scottish Region close at hand, which has a gradient of 1 in 60, the National Engineering Laboratory is conveniently situated for practical studies of the adhesion of locomotive wheels to the rails they run on. And as it is commonly supposed by railwaymen that the onset of a light shower is very much more severe in reducing adhesion than a continuous downpour, it was thought to be helpful to test objectively the validity of this view. Accordingly, Dr. F. T. Barwell, then at the laboratory, and his colleagues set to work with a microphone and tape recorder. A preliminary account of their findings is published in the July issue of the *Journal* of the Junior Institution of Engineers.

A good indication that a locomotive was slipping badly was provided by the noticeable change in the beat of the exhaust. So a microphone was set up some 500 yards from the track and connected to a tape recorder. A set of contacts mounted on the track switched on the recorder for two minutes when a train went up the gradient, simultaneous readings being taken of weather conditions. It was a simple matter to play back the tape at weekly intervals and work out the correlation between slipping and rainfall, with the aid of a Hollerith machine. The full analysis is not yet available, but the preliminary results — shown in the illustration — confirm railwaymen's feelings about the detrimental effects of light showers.

« Dirty » rail heads.

The actual surface of the rail is subject to continuous oxidation, and has deposited on it foreign matter from various sources. The result is a colloidal material that accumulates in numerous microscopic pockets. A sampling method was worked out at the Laboratory, based on a suggestion by London Transport Executive, to discover the nature of the colloidal material. Two layers of cellulose acetate were clamped to the head of the rail prior to the passage of a train. The rolling action of the wheels caused the debris to adhere to or be embedded in the cellulose acetate, which could then be removed in a solvent in the Laboratory, so as to produce a fair sample of the foreign matter present. By using two strips, it was possible to segregate the material adhering to the wheel from that present on the rail head. Analysis showed that the debris consisted of metallic iron, Fe_3O_4, silica, and a compound believed to be a hydrated form of iron oxide.

Sampling was carried out over a very long period to see if variations in the coefficient of adhesion from time to time might



Measurements at Nel confirm railwaymen's belief that light showers are more likely to cause wheel slipping than a heavy downpour.

be attributable to changes in the nature of the colloidal deposit. As far as inorganic constituents were concerned, the composition was found to be remarkably constant over the whole period. There is some indication, however, that adhesion conditions might be affected by the amount of debris present. An important point is that the particular tests gave no information about the amount of organic matter present — lubricating oil from rolling stock, for example — as this would be dissolved away in the solvent used to put the cellulose acetate into solution. Nor was information on the amount of water absorbed on the debris afforded.

Chemical cleansing.

The prolonged effect of heavy rain, as distinct from light drizzle, suggests that the cleaning which the rails presumably received could be carried out by chemical methods. An investigation of sodium metasilicate on one of the wheel-adhesion machines in the Laboratory showed that the solution could overcome the effects of heavy contamination with a fatty acid. In the United States, the same material has been shown to be of commercial value, when applied to a particularly troublesome gradient on the system of the Reading Company.

Application of the fluid from the locomotive itself was found to be ineffective, as a certain time was required for the action to take place. However, by using a separate truck, beneficial results were obtained. This truck operated over the Catawissa Grade — average of 1 in 166 for 35 miles with a mile of level track at midpoint — and made a round trip in 8 h, five days a week. About 25 gallons of fluid were distributed per trip. During the first year of operation of the truck, the traffic over the section was handled with 14 % fewer trains and 4.7 % fewer locomotives than could be moved without rail conditioning.

The true reasons for the value of sodium metasilicate in assisting adhesion is a matter for controversy. Dr. Barwell considers that the substance hydrolyses to form a mild alkali that reacts with oily matter to give rise to a simple detergent action. The view of American workers is that the deposition of colloidal silica acts in the same way as conventional sanding. A possible alternative view is that both elements contribute to the cleaning action, the alkalis providing detergency, and the colloidal matter providing a large surface area for the absorption of surface active material.

[656 .212 .8 (42)]

Driverless platform trucks for goods depot.

Electronically guided battery vehicles at Wolverhampton Herbert Street, Western Region, following energised under-floor wire.

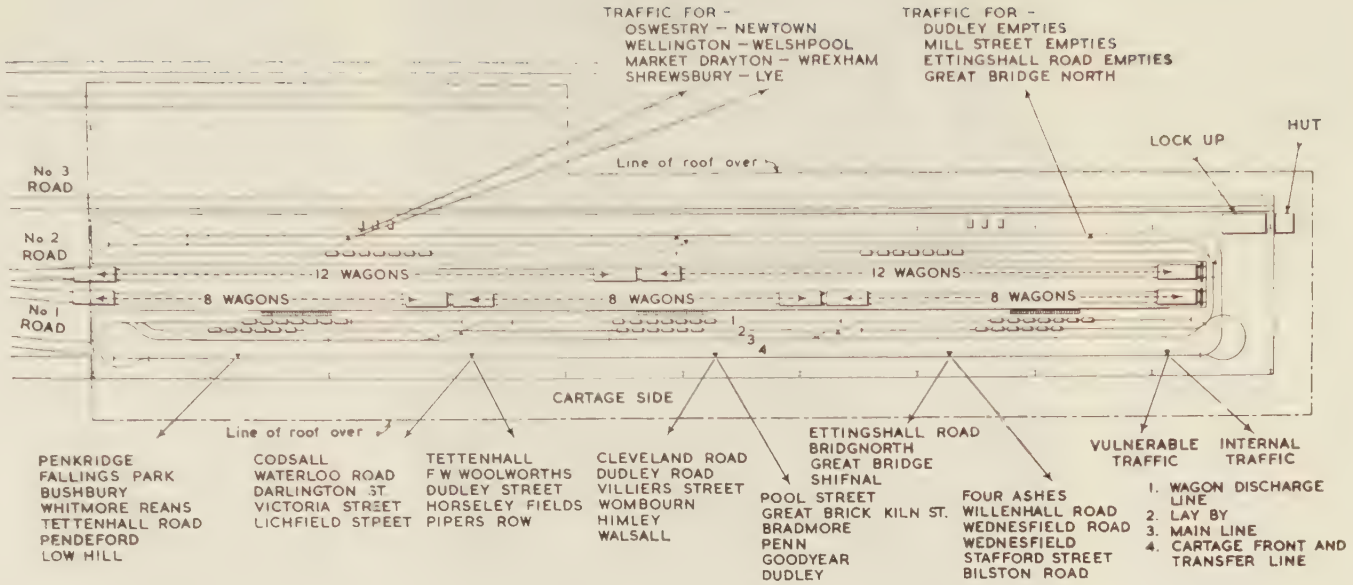
(*The Railway Gazette*, September 23, 1960.)

The mechanical handling scheme for sundries traffic at the Wolverhampton Herbert Street goods depot of the Western Region, British Railways, involving use of electronically-controlled driverless trucks, known as Robotugs, is the result of two years' study and experiment by British Railways and E.M.I. Electronics Limited. Experience was gained with an installation in the goods shed at Newton Abbot, in the Western Region. This was described briefly in our April 24, 1959, issue. Two Robotugs were used.

In the pilot installation at Wolverhampton five Robotugs are in use. Walking by the staff has been eliminated, and there are no fixed tracks or conveyors to impede the free movement of vehicles or staff along the platforms. Sorting is carried out as packages are removed from wagons and the loaded trolleys then automatically delivered to the correct delivery station of the cartage berth.

Removing loaded trolley at cartage berth.

Each Robotug hauls six trolleys, stopping at each station of the cartage berth, which has been selected by the despatcher,



Layout of Robotug installation at Wolverhampton Herbert Street.

for uncoupling a loaded trolley. Empty trolleys are attached, and the tug returns to the despatcher.

The tug moves at 2 m.p.h. It is accurately guided along its path by a signal wire laid 1/2 in. below the platform surface. Each of the several tug routes is divided into sections and block working is used as in normal railway practice to prevent a tug entering a section already occupied.

Operating procedure.

The two platforms cover an area of 2 415 sq. yd. On each platform there are four tug tracks. These are: a wagon discharge line, lay-by, main line, and cartage, post and transhipment line. The platforms are divided into three sections of eight wagons each on No. 1 road and two sections of 12 wagons each on No. 2 road.

Tug and trolleys on main track passing trolleys in cartage berth.

Re-starting is automatic as the section is cleared.

At the Herbert Street depot the daily average discharge rate is 16 tons, covering about 5 000 packages. The shed accommodates 74 wagons on three roads. Roads 1 and 2, which are used for inwards wagon discharge, accommodate 48 wagons. The cartage berth accommodates 60 road vehicles and the number of wagons discharged daily is about 86. Local, zonal and other deliveries are shown on the diagram.

Each of the five gangs is equipped with a Robotug, 12 trolleys, and a 25-ft. length of light-weight moveable rollers.

On the track layout are 12 programmed stops. Five of these are homing stops for the tugs at the trolley loading stations and four are at the cartage berth. Porters discharge from the wagons on to the roller-top stand, where the checker sorts the trolley loads for the respective cartage and transfer stops.

The switches on the programme unit

of the tug are selected in accordance with the trolley loading, and the tug despatched. At the cartage or transfer stations the checker releases the automatic coupling of the trolleys to be detached, replaces these with empties, and re-starts the tug. In the case of suitable unit loads the trolleys are wheeled direct on to the road cartage vehicle and taken by road and unloaded at the consignee's premises.

Small turning circle of Robotug and trailer trolleys.

At the end of the cartage line is a loop in the track. If all programmed stops have been cleared before this point, the tug is by-passed by the loop back to its homing station, without completing a circuit of No. 2 road platform. At the homing station empty trolleys are parked in the lay-by section for use as required. Unloading of wagons and sorting and checking of consignments proceed at the roller-top stand while the loaded tug is in transit.

Electronic control of Robotug.

The Conveyancer — E.M.I. Robotug is a three-wheel battery electric truck of conventional type with power-controlled steering. The turntable of the driving motor, mounted over the single traction and steering wheel, is connected by a chain reduction gear to the servo steering motor. Battery capacity suffices for a normal 8-h shift, with the truck operating at 2 m.p.h. At the leading end is an apron carried on four springs. Immediately this touches an obstruction the truck is stopped. The side skirts are brought well down to floor level to deflect loose obstructions.

Guiding wire.

The underfloor guiding wire carries an A.C. current flow of 1/6 A. This is detected by two sensing coils carried at floor level

on the front of the truck. In the correct travel position the induced current in each coil is the same and the servo steering motor remains stationary.

When the truck tends to leave the track of the wire, the coil current becomes unbalanced. Working through a relay, the servo steering motor is energised in the required direction to restore the correct tracking of the truck. If the truck leaves the track, or the signal current fails, the driving motor is stopped and the brakes are applied.

Programming unit.

The electronic programming unit is contained in a small removable panel with plug-in connections. Transistors are used in the electronic control circuits. A wall-mounted indicator at the loading point indicates to the checker the station position of the tug on the track circuit.

A steering handle is carried on each tug. If required, the tugs may be controlled by a pedestrian operator or by one riding on the truck for point-to-point working either inside or outside the track circuit area.

Much experiment has been undertaken in the design and selection of the most suitable trailer, as the number required forms a large part of the capital outlay involved. A small turning circle was an essential requirement, but track steering to obtain this was considered to be too expensive. The design adopted incorporates twin castor wheels at the trailing end and a sliding towbar at the fixed-wheel end.

Suitability for narrow platforms.

This arrangement is stated to have produced very satisfactory tracking and a turning circle diameter of tug and trailers of only 12 ft. 6 in., making the installation suitable for narrow platforms. The advantages of the spring-loaded sliding towbar are that the trolleys close up to the minimum overall length. This reduces walking by the staff at the loading section, and the motor and battery loads are greatly reduced by the gradual take-up of load when starting. Danger to staff is minimised because there are no gaps between the trolleys. Coupling is automatic when the trolleys are pushed together.

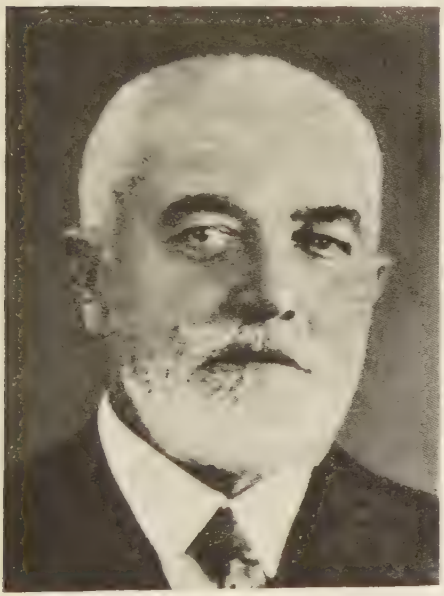
This scheme can be varied to suit fluctuations in traffic. Automatic operation of the trucks is considered to be safer than manual operation and maintenance is expected to be less. Despatch errors and split loads should be reduced by the elimination of intermediate handling and checking.

OBITUARY.

Raoul-Jean PAUL,

Honorary General Manager of the P.O.-Midi Company.

Former Member of the Permanent Commission of the International Railway Congress Association.



We announce with regret the death on the 28th September last of M. Raoul-Jean PAUL, former General Manager of the P.O.-Midi Company and former Member of the Permanent Commission of our Association.

M. PAUL was born on the 8th May 1869 at Vayres (Gironde). He studied at the « Collège de Libourne », then at the « Lycée Montaigne » at Bordeaux. He entered the Polytechnique in 1887, at the age of 18, and left with first class honours in civil engineering.

He entered the Midi Company in 1897, as Permanent Way engineer, and immediately distinguished himself both by his technical skill and by his qualities of leadership. Owing to his exceptional qualities, he was appointed in 1910 — at the age of 41 years — Chief Operating Manager of the Midi Railway Company, and then General Manager in 1913.

There was no field of railway activity with which he was not familiar: in the case of signalling, he perfected, in collaboration with the engineer DUCOUSSEAU, one of the first automatic blocks by means of track circuits, the P.D. (1915) block; in the case of passenger transport, he created in 1928 the first Diesel railcar « La Pauline » for the economic operation of small lines.

To encourage tourist traffic, he started in 1920 the « Mountain Railways and Hotels Company » as well as the first tourist motor tours in the Pyrenees.

But it was in connection with electrification that he distinguished himself in particular. Although small electrification projects had already been attempted as far back as 1900 (Paris-Versailles, left bank, Paris-Orsay, Paris-Austerlitz) and in 1901, St. Gervais-les-Bains-Chamonix, it can be said that M. PAUL was indeed the « father » of electric traction. Begun in 1911 with

single phase 16 2/3 cycles on the Perpignan to Villefranche-Vernet-les-Bains, this electrification extended to Pau-Montrejeau and the connecting Pyrenean branch lines.

Soon after the 1914-1918 war, occurred the great extension of electric traction with 1 500 V D.C. to the Bordeaux-Dax, Toulouse-Bayonne, Beziers-Neussargues and, finally, Montauban-Sete lines.

His inexhaustible activity however extended far beyond railway horizons : builder of dams and high tension lines for the Pyrenean electrification project, he was also behind the creation of numerous industries set up in this region. He was also administrator of the Bordeaux and Tunis Tramways, as well as of the Tunisian Electricity Company.

In 1931, M. PAUL was made a Grand Officer of the Legion d'Honneur.

Such was the career of this striking personality of the French railways, which we have taken from the « Vie du Rail ».

M. PAUL was also an eminent member of the Permanent Commission of our Association. He was appointed a member at the Rome Congress in 1922 and in spite of his many absorbing duties, always showed the greatest interest in the work of our Association.

He represented the Midi Railways Company at the London Congress (1925), Madrid Congress (1930) and Cairo Congress (1933).

In the name of the Association, we offer his family our sincerest sympathy.

The Executive Committee.

NEW BOOKS AND PUBLICATIONS.

[656 .28 (42)]

Brigadier C.A. LANGLEY, Chief Inspecting Officer of Railways, Ministry of Transport. Railway Accidents. **Report to the Minister of Transport and Civil Aviation upon the Accidents which occurred on the Railways of Great Britain during the year 1959.** — A brochure (6 · 9 1 2 in.) of 88 pages with tables and graphs. — 1960, Her Majesty's Stationery Office, York House, Kingsway, London W.C.2 and 423 Oxford Street, London W.1. (Price : 5/— net).

After reporting a reduction in the total number of accidents and number of those killed and injured, during the year 1959, the report examines in detail, with the aid of tables and graphs, for the previous years, the details and different causes of these accidents.

It gives in particular the results of enquiries held after accidents.

The report also gives a review of the important work done in connection with the permanent way, electrification, signalling, modernisation, etc., during 1959, as well as the operating results.

The reduction in the number of accidents is attributed to the modernisation of the rolling stock, the fixed installations and to the great care always being taken to improve operating, maintenance and repair conditions.

As regards accidents due directly to the human factor (running past signals at danger, signalman's mistake, etc.) the number of these is still relatively high. A special Commission has been set up to examine such cases.

The reporter concludes by stating that railway safety depends upon the spirit of discipline of railway employees, on their professional conscience and their intelligent respect of the regulations, as well as upon the conditions of maintenance of the permanent way, the bridges, fixed installations and rolling stock.

W. v. R.

[385 (09 (3)]

World Railways 1960. A worldwide survey of Railway Operation and Equipment. — Collected and edited by Henry SAMPSON. — One volume, bound (8 3/4 · 13 in.) of 412 pages with numerous maps and illustrations. — 1960, London W.1., Sampson Low's « World Railways » Ltd, 16, Maddox Street. (Price : £ 5.5.0 d. net).

The preface to this work, which is in the form of an encyclopaedia, reviews the most recent tendencies noted in the railway world, both as regards traction and rolling stock, and the development of electrified lines and modernisation of signalling, etc.

The work is then divided into four parts, which give :

1) for each company, the size of the railway system, its traction and rolling stock, amount of traffic, financial results, general characteristics of the stock and the permanent way;

2) for each country, a map of the railway system, details of the financial results, details about the installations, the stock, electrification, the gauges in current use, and a list of the main builders with photographs of the material built;

3) information about underground railway installations;

4) the characteristics of the Diesel traction units built in each country.

W. v. R.

[**385** .13 (43)]

CHATEL (Marcel), Honorary Chief Engineer of the French National Railways, former Manager of the « Compagnie des Ateliers des Forges de la Loire ». – **La traction à moteurs thermiques** (*Traction by means of thermal engines*). — One volume (6 1/4 × 9 3/4 in.) of 440 pages, with 254 figures and 33 photographic plates in addition to the text. – Paris (5e), Editions Eyrolles, 61, Boulevard Saint-Germain. (Price : 50 NF).

During the last twenty years, railway traction has undergone a profound evolution and has deliberately chosen to take new paths, leaving aside steam traction in favour of electric and Diesel traction.

The success enjoyed by the latter has fully justified the hopes placed on them and their development continues to extend from day to day as a harmonious whole : electric traction on the main lines and Diesel traction on lines which it would not be a paying proposition to electrify.

The time is therefore ripe to collect together for the use of research and operating engineers in a general report taking into account the most recent data and most modern realisations, the fundamental principles governing the design, construction and working of these new engines.

M. CHATEL's book on traction by means of thermal motors meets this need perfectly and the author is particularly well qualified to write it since during the course of his career he has been both research engineer, maintenance engineer, and maker and user of such engines.

Because of the utilitarian objective he has set himself — « to make available to engineers a manual throwing light upon the problems constantly arising » — M. CHATEL has on the one hand passed over in silence in his report the well known classical questions of railway technique as well as technological descriptions of motor equipment, in order to insist on the other hand, in a simplified form whenever this is possible without jeopardising the unfolding of the argument, on certain less well known problems, which are however of capital importance, such as the study of oscillatory phenomena and that of the dynamic stresses of locomotives.

Parts I and II are devoted to the mechanical part, the body and bogies, and engines. Side by side with theoretical studies on periodic movements, the dynamics of parasitic movements and on the vibration of the shafts, he gives practical considerations on the design of bodies and bogies.

Parts III and IV are specially devoted to the motor equipment, Diesel engines and gas turbines on the one hand, mechanical, hydraulic and electric drives on the other. After recalling the general notions on the functioning of these components, the author stresses their fundamental characteristics, in relation to their use in railway traction.

Part V collects together the necessary notions concerning the auxiliary engines used on Diesel units, whilst part VI is devoted to traction and operating problems. A complete economic study of Diesel traction, as well as a comparison with steam and electric traction, are particularly interesting.

To sum up, M. CHATEL'S work is a remarkable documentation on tractive units with thermal engines, and it is to be hoped that it will receive widespread attention from all technicians interested in railway traction.

R. S.

[385 .13 (43)]

Dr. jur. F. HERETH, Ausburg. — **Steuerbegünstigungen und Wettbewerbslage der Deutschen Bundesbahn** (*Fiscal advantages and competitive capacity of the German Federal Railway*). — Supplement No. 6 (February 1960) of the review « Die Bundesbahn ». — One brochure (7 7/8 × 11 1/2 in.) of 32 pages. — Darmstadt, Carl Röhrig Verlag.

This study which appeared as supplement No. 6 to the review *Die Bundesbahn* proposes to set out the exact position of the D.B. as regards the fiscal advantages it is reputed to enjoy, and what effect this has upon its competition with river, road and air transport.

The Author first of all makes a distinction between the real fiscal allowances and those which are only nominal or those cases where it would be unjust to impose such taxes. In the latter category in particular would be rates and taxes upon the permanent way : the competing methods of transport do not own the means of communication of which they make use and do not pay any taxes on them; and yet, the remission of taxation granted to the D.B. is only nominal.

The remission of rates and taxes is only real in the case of service buildings; it does not apply moreover to service accommodation, etc.

As regards taxes on capital, it would not be just to impose such taxes, since from the time its accounts were opened in June 1948 the D.B. balance sheet has shown liabilities under this heading. The author also makes the point that there should be exclusion at least of the capital invested in lines and stock retained for national defence purposes and those lines which are run at a loss and would long ago have been abandoned by any undertaking that was not bound by its obligations as a public service.

The author analyses in detail tax relief granted in the case of industrial productivity, on wages, on the number of men employed, from the point of view of the effects on the transmission tax and capital reserves. He shows how very difficult it is to determine exactly the amounts involved as the headings of the balance sheet and accounts do not provide the precise details required. However, an estimate has been made of the maximum value and the author points out that this is very low compared with the total deficit shown each year on the balance sheet; these reliefs therefore bring very little benefit to the D.B. from which it can effectively profit.

Going on to examine the relief granted to other methods of transport (river navigation and air transport in particular), the author has stressed the fact — most detrimental to the D.B. as he makes it clear — of tax remission on motor fuel (Diesel fuel and benzine). As the transport rates are more closely in line with the costs, in the case of the boat services in particular than for the railway services, tax remission gives advantages of great practical value to the boat services.

The fiscal position of the D.B. is therefore very far from being beneficial as the author shows : in addition this leads to an unatural distribution of the traffic.

P. Sch.

Competition organized by the review « Eisenbahntechnische Rundschau ».

On the occasion of the 125th anniversary of the German Railways, a competition is being organized by the « Eisenbahntechnische Rundschau » on the subject : *the future improvement of railway technique*. Numerous prizes will be granted to the winners of this competition.

The papers to be submitted must be thorough studies on a problem relative to the various branches of railway activities.

The rewards granted are as follows :

first prize : 12 000 DM;

several 2nd prizes of 6 000 DM each;

several 3rd prizes of 3 000 DM each.

For full information, please apply to : *ETR-Preisausschreiben, Carl Röhrig Verlag, Darmstadt, Holzhofallee 33 a.*

MONTHLY BIBLIOGRAPHY OF RAILWAYS[1]

PUBLISHED UNDER THE SUPERVISION OF

P. GHILAIN,

General Secretary of the Permanent Commission of the International Railway Congress Association.

(FEBRUARY 1961)

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GÖPEL (W.). — **Cooling units for Diesel motive power.** (2 800 words & figs.)

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1960 **621** .332
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PAGANELLI (M.). — Alcuni aspetti metallografici evati su provette di **lega leggera sollecitate a fatica.** 000 parole & fig.)

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1960 656 .223
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BIANCHI (M.). — **Un semplice metodo risolutivo problemi dei trasporti.** (3 500 parole & fig.)

1960 625 .213
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Sospensioni elastiche italiane all'Estero. (800 parole & fig.)

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DE PREE (J.A.). — **Het maatschappelijk werk van de stichting voor Socialen Bijstand aan spoorwegpersoneel.** (*Vervolg.*) (2 500 woorden & fig.)

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VAN LITH (H.A.). — **De Brünigbahn.** (1 000 woorden & fig.)

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MOTCHENOV (I.G.). — **Régulation automatique de la tension des sous-stations de traction électrique.** (2 000 mots & fig.)

1959 **621** .431 .72 = 491 .7
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TOURIK (N.A.) et KIRILLOV (Y.G.). — **L'autorail Diesel TG 100 pour voies principales,** à transmission hydromécanique. (1 600 mots & fig.)

1959 **621** .431 .72 = 491 .7
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YEGOUNOV (P.M.). — Sur le choix d'un régime optimum de **refroidissement du moteur 2D 100.** (2 100 mots & fig.)

1959 **621** .335 = 491 .7
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SORINE (N.A.). — Les particularités principales de la construction, les données techniques et le schéma de ventilation de la **locomotive électrique N 60.** (1 200 mots & fig.)

1959 **621** .337 = 491 .7
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KOTCHOURAIEV (L.D.). — **La régulation des appareils électriques de la locomotive électrique WL 23.** (1 100 mots.)

1959 **625** .25 = 491 .7
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KLIKOV (E.V.) et KONOPLEV (Y.M.). — **Freinage automatique des trains électriques** en tenant compte de leur charge. (1 000 mots & fig.)

1959 **621** .31 = 491 7
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ROUDNIEV (V.N.). — **Un procédé simple pour réduire le nombre d'amorçages en retour dans les redresseurs à vapeur de mercure.** (700 mots & fig.)

1959 **621** .335 = 491 .7
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DOUBROVSKY (S.M.). — **Le schéma électrique de la locomotive électrique série F.** (5 900 mots & fig.)

1959 **625** .285 491 .7
Eléktritchéskaïa i tyéplovaïa tyaga, août, p. 7.
PLOUTZER-SARNO (Y.N.). — **Le système d'excitation de la génératrice de traction de l'autorail Diesel TE 10.** (2 900 mots & fig.)

1959 **621** .331 = 491 .7
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ALKHANOV (A.S.). — **La commande automatique des redresseurs de sous-stations de traction** en fonction de la charge. (1 400 mots & fig.)

1959 **621** .135 = 491 .7
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CHIRYAYEV (A.P.). — **Blocage du patinage des essieux montés des locomotives** par la méthode du freinage léger (anti-patinage). (1 300 mots & fig.)

1959 **625** .28 = 491 .7
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MAXIMOVITCH (L.N.). — **La reconstruction des fosses de visite lors de l'introduction de nouvelles formes de traction.** (1 200 mots & fig.)

Vyésstnik Vsesoyousnowo Nautchno-Issledowatelskowo Institouta Jelezno-Doroznowo Transporta. (Moscou.)

1960 **656** .212 .5 = 491 .7
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FONARYEV (N.M.). — **L'automatisation du processus de débranchement dans les gares de triage mécanisées.** (3 600 mots & fig.)

1960 **625** .14 (01 = 491 .7
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ABACHKINE (V.V.), DEVYATKOV (V.F.), KOUDRYAVTSEV (I.I.), PAVLOV (I.W.) et CHARONINE (V.S.). — **L'appréciation de l'état de la voie** par l'action des forces mutuelles entre rails et le matériel roulant. (2 100 mots & fig.)

1960 **625** .22 = 491 .7
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BOITCHEVSKY (O.G.) et GREBYENYOUK (P.Ch.). — **Les forces dynamiques longitudinales dans les trains de 7 500 t.** (1 300 mots, tableaux & fig.)

1960 **625** .143 = 491 .7
Vyésstnik Vsesoyousnowo Nautchno-Issledowatelskowo Institouta Jelezno-Doroznowo Transporta, n° 1, p. 20.
YERCHKOV (O.P.). — **Le calcul du rail par l'action des forces latérales.** (1 800 mots.)

1960 **625** .123 = 491 .7
Vyésstnik Vsesoyousnowo Nautchno-Issledowatelskowo Institouta Jelezno-Doroznowo Transporta, n° 1, p. 24.
BOLOTINE (W.I.). — **Influence du drainage superficiel de l'eau sur la stabilité de la fondation des rails.** (1 300 mots & fig.)

1960 **656** .222 .4 = 491 .7
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KARETNIKOV (A.D.). — **Répartition rationnelle des points d'évitement** lors de l'élaboration des graphiques de trains pour lignes à double voie. (2 400 mots & fig.)

1960 **656** .222 .4 = 491 .7
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OSSIPOV (V.T.). — Le calcul technico-économique comme fondement d'une **planification des itinéraires.** (2 600 mots.)

1960 656 .232 = 491 .7
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KOUPTSOV (W.S.). — **Sur l'appréciation de la leur du voyageur-heure.** (2 200 mots.)

1960 656 .225 = 491 .7
vésstnik Vsesoyousnowo Nautchno-Issledowatelskowo Institouta Jelezno-Doroznowo Transporta, n° 1, p. 40.
POVOLOTSKY (D.S.). — Compactage du charbon 'aide d'une méthode vibratoire dans le but d'améliorer tilisation de la **capacité de chargement.** (1 900 mots fig.)

1960 656 .222 .3 = 491 .7
vésstnik Vsesoyousnowo Nautchno-Issledowatelskowo Institouta Jelezno-Doroznowo Transporta, n° 1, p. 43.
POSAMANTYR (E.I.). — L'**efficacité de la formation s trains** d'après le poids (formation distincte). (2 300 ots & fig.)

1960 625 .113 = 491 .7
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NIKOLAÏEV (I.I.). — Sur les tâches à résoudre r la **méthode géométrique d'inscription dans les courbes.** 0 mots & fig.)

1960 669 = 491 .7
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BOUCHÉ (N.A.). — Sur **la mise à profit des métaux es** dans le transport ferroviaire. (1 500 mots.)

In Russian (+ German and Chinese) (= 491 .7).

Bulletin de l'OSShD. (Varsovie.)

959 351 .812 = 491 .7
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REŽÁBEK (J.). — **Le droit international socialiste s le transport ferroviaire.** (2 100 mots.)

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959 625 .25 = 491 .7
lletin de l'OSShD, n° 6, p. 4.
KASARINOV (V.M.). — **Sur le choix de la méthode calcul des freins de wagons à marchandises sur les mins de fer membres de l'OSShD.** (2 600 mots & fig.)

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959 625 .214 = 491 .7
lletin de l'OSShD, n° 6, p. 10.
TIMOCHENKOV (I.T.). — **Roulements à rouleaux** véhicules des chemins de fer et leur unification. 00 mots & fig.)

1959 656 .254 = 491 .7
Bulletin de l'OSShD, n° 6, p. 15.
PIASTOWSKI (J.). — Le **réseau international des télécommunications** entre les membres de l'OSShD. (II[e] partie.) (1 600 mots & carte.)

1960 656 .2 (517) = 491 .7
Bulletin de l'OSShD, n° 1, p. 3.
LEGDEN DAMDINHAW. — La **planification des transports transitaires** aux Chemins de fer de Mongolie. (1 200 mots.)

1960 656 .2 (51) = 491 .7
Bulletin de l'OSShD, n° 1, p. 5.
HUAN DO. — Sur le **développement de l'exploitation des Chemins de fer de la République Populaire de Chine.** (2 000 mots.)

1960 656 .225 = 491 .7
Bulletin de l'OSShD, n° 1, p. 11.
HOFMANN (K.). — **Containers flexibles** pour le transport des matières liquides et pulvérulentes. (1 300 mots.)

In Swedish (= 439 .71).

Järnvägs-Teknik. (Stockholm.)

1960 621 .335 (485) = 439 .71
Järnvägs-Teknik, n° 7, p. 167.
TOREDAL (A.) et MARLUND (B.). — **Nouvelles locomotives électriques des Chemins de fer Suédois** pour la ligne de minerais en Laponie. (4 000 mots & fig.)

1960 621 .331 (485) = 439 .71
Järnvägs-Teknik, n° 7, p. 174.
EDENIUS (R.). — L'**alimentation en énergie électrique des Chemins de fer Suédois** et son développement historique. (2 500 mots & fig.)

1960 625 .215 = 439 .71
Järnvägs-Teknik, n° 7, p. 178.
LORUP (O.). — L'**entretien des bogies** et les conditions de son organisation. (1 800 mots.)

In Czech. (= 91 .886).

Inženýrské Stavby. (Prague.)

1960 624 = 91 .886
Inženýrské Stavby, n° 11, p. 427.
HANÁK (B.). — **Calcul simplifié de constructions statiquement indéterminées.** (2 000 mots & fig.)

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1959 **656** .225 (437) = 91 .886
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VYPLEL (O.). — Les problèmes principaux d'**utilisation des containers et des palettes** en Tchécoslovaquie. (3 500 mots.)

1959 **621** .133 .1 = 91 .886
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ČERNOHORSKÝ (V.). — Application des corrélations non linéaires lors du **calcul des normes de consommation de combustible.** (1 200 mots & tableaux.)

1959 **656** .25 = 91 .886
Železniční doprava a technika, juin, p. 177.
SETINA (Z.). — **Sécurité de mouvements de trains sans signaux fixes dans la voie.** (2 000 mots & fig.)

1959 **656** .222 .1 = 91 .886
Železniční doprava a technika, juin, p. 179.
GOTTMANN (F.). — **Influence d'une augmentation de la vitesse des automotrices électriques sur les intervalles et sur le débit de la ligne.** (3 600 mots & fig.)

1959 **625** .212 = 91 .886
Železniční doprava a technika, juillet, p. 196.
STEJSKAL (V.). — Les **roues monoblocs** perfectionneront le transport ferroviaire. (2 900 mots & fig.)

1959 **621** .3 = 91 .886
Železniční doprava a technika, juillet, p. 202.
CHOCHOL (B.). — **Un interrupteur ultra-rapide RV 15/30.** (3 100 mots & fig.)

1959 **625** .26 (437) = 91 .886
Železniční doprava a technika, juillet, p. 210.
VESELÝ (J.). — Elaboration des normes de travail techniquement bien justifiées dans les **ateliers de réparation de wagons** des chemins de fer tchécoslovaques. (2 900 mots & tableaux.)

1959 **656** .215 = 91 .886
Železniční doprava a technika, juillet, p. 217.
VILD (J.). — **Emploi de l'éclairage fluorescent dans les halles des remises à locomotives.** (2 700 mots & fig.)

1959 **656** .254 = 91 .886
Železniční doprava a technika, août, p. 227.
CAIS (B.). — **Emploi des radio-télécommunications et de la radiotéléphonie dirigée dans le service ferroviaire.** (2 900 mots & fig.)

1959 **625** .28 = 91 .886
Železniční doprava a technika, août, p. 232.
GOTTMANN (F.). — Quelques conséquences économiques d'exploitation de la **traction ferroviaire dépendante et indépendante.** (4 400 mots & fig.)

1959 **656** .212 .5 = 91 .886
Železniční doprava a technika, août, p. 238.
KLIMEŠ (F.). — **L'automatisation du travail sur les voies de tiroir** des gares de triage. (2 000 mots & fig.)

1959 **621** .8 = 91 .886
Železniční doprava a technika, août, p. 245.
MICHÁLEK (M.). — Les caractéristiques des **transmissions hydrauliques.** (3 200 mots & fig.)

M. Weissenbruch & Co., Ltd., Printer to the King, 49, rue du Poinçon, Bruxelles

M. WEISSENBRUCH & Co. Ltd.
Printer to the King
(Manag. Dir.: P. de Weissenbruch,
238, chaussée de Vleurgat, XL)

Edit. responsible: P. Ghilain

PRINTED IN BELGIUM